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**LOCKHEED MARTIN**

EPI HLW-102 1104

## Lockheed Martin Idaho Technologies Company

### INTERDEPARTMENTAL COMMUNICATION

Date: April 16, 1999

To: D. J. Harrell MS 3211 6-9160

From: M. D. Staiger *Dan Staiger* MS 3211 6-3122

Subject: Modified Tank Farm Residual Estimate - MDS-07-99

- References:
1. Letter from M. D. Staiger to D. J. Harrell, *Tank Farm Residual Update MDS-06-99*, dated 5 March 1999
  2. Letter from M. D. Staiger to J. T. Beck, *Residual Inventories for Tank Farm Calcined Storage*, MDS-02-98, dated 17 June 1998
  3. Email from D. J. Harrell, *Tank Farm Closure Assumptions*, dated 6 April 1999

Estimates<sup>1,2</sup> of the residual activity in the tank farm vaults and tanks were provided earlier. These estimates were made assuming that the tank heels were to be flushed with water to make the heels suitable for grouting. This earlier estimate neglected settled solids in the tanks. Solids samples from tank WM-188 were recently retrieved. The residual estimate has been revised to reflect new information. Calculational estimates conform to the current assumptions<sup>3</sup> relative to heel flushing.

In the attachments the activity associated with each tank-vault system is reported. The residual activity trapped in the sand support pad for WM-185 and WM-187 and the settled heel solids constitute the bulk of activity.

C. M. Barnes performed a cursory review of the spreadsheet and found no errors.

The calculation assumptions are stated in Attachment I. The residual estimates are given in Attachments II, III, and IV. Supporting documents are attached as Attachment V

If you have any questions or if I can be of further assistance, please contact me.

#### Attachments

cc: C. M. Barnes, MS 3625  
J. T. Beck, MS 3208  
M. B. Heiser, MS 3211  
W. B. Palmer, MS 3211  
J. H. Valentine, MS 3211  
M. D. Staiger letter file

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Assumptions.

1. Preclosure tank inventories are given in the Tank Farm planning report, *ICPP Tank Farm Planning Through 2012*, INEEL/EXT-98-00339, dated April 1998. [<sup>137</sup>Cs activity in this report is not significantly different than reported by Schindler in his February 1999 letter, Schi-04-99 with the exception of WM-182, which decreased by a factor of four due to flushing activities that have taken place since the earlier report. For consistency with earlier residual estimates the earlier reported activities were used in this new estimate.]
2. Each tank has a very limited pedigree with respect to radionuclides in either the liquid or solids. To overcome this deficiency, inventories for typical waste types at INTEC have been prepared by D. R. Wenzel. Wenzel generated these inventories using established codes as described in his attached letter reports. He "built" his model to simulate what was observed to be in a typical waste type. These residual calculations assume that the waste existing in the individual tank heels is represented by the sodium bearing waste. The inventories were calculated by normalizing the calculated inventories to the activity of the <sup>137</sup>Cs (decayed to 2016) measured in the tank. Wenzel's estimates were originally calculated to, at-the-time, important environmental restoration dates. The calculations for the year 2016 were chosen, for this estimate of the residuals, because the date is close to the planned date for closure of the tank farm. Further, the date is satisfactory for residual calculating purposes because the wastes are relatively old; and short lived constituents have sufficiently decayed to insignificant levels while longer lived nuclides such as <sup>137</sup>Cs and <sup>90</sup>Sr are still present. For very long lived nuclides the choice of 2016 is of little consequence.
3. Tank solids are estimated to be one inch thick with a porosity of 46%. The thickness of the solid layer is a conservative "guess" based on the recent video inspections of the inside of tank WM-188. The porosity conforms to the voids observed in loose packed uniform sand. The solids are assumed to be completely removed from the internal surfaces except the tank bottom. It was assumed that the solids radioactivity is derived from a variety of sources and is best represented by the sodium bearing waste type. Again radionuclide distributions were calculated based on Wenzel's estimate by normalizing to the measured <sup>137</sup>Cs concentration from WM-188. Concentrations of <sup>238</sup>Pu, <sup>239</sup>Pu, <sup>237</sup>Np, and <sup>241</sup>Am were corrected to agree with sample results. Sample Log 9902104 has been attached.
4. Interstitial liquid in the heel solids is assumed to be the liquid filling the particular tank as indicated in assumption number 1 above after dilution to pH 2.
5. Flushing operations will disturb most of the solids on the bottom of the tank thus achieving dilution of the activity trapped in the interstices. However, a 10% fraction was assumed to be shielded from agitation and therefore does not experience dilution of the interstitial liquid.
6. Interstitial liquid radiochemical concentrations are calculated from D. R. Wenzel's predicted values reported in letter Wen-23-97, *Calculation of Radionuclide Inventories for Sodium Bearing Wastes*, normalized to the <sup>137</sup>Cs concentration in assumption number 1.

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7. Heel liquid radiochemical concentrations are normalized as in number 6 above after the heel has been rinsed to pH 2.
8. The calculation assumes that the heel solids are the same for all tanks a bulk density of 1.22 g/cm<sup>3</sup> is reported by Log 9903016. This wet bulk density was corrected to a dry particle density of 1.65 g/cm<sup>3</sup> assuming that the porosity is 34% that the interstices were filled to 30% by 1.28 specific gravity solution.
9. WM-190 residuals are calculated as if the tank were filled with SBW in the future with <sup>137</sup>Cs activity as per assumption number 1 above.
10. The tank support sand pads under WM-185 and WM-187 were significantly contaminated with aluminum type waste during siphoning incidents in March 1962. The interstitial volume of the sand pad under tanks WM-185 and WM-187 is calculated at 2100 gallons assuming a porosity factor of 0.34. This porosity factor is based on the reported value for packed uniform sand given in a handbook, *Soil Mechanics in Engineering Practice* by K Terzaghi and R. B. Peck, John Wiley and Sons, 1967. Infiltration water (from surface water run-off) flushing of the sand pad has occurred since the siphon event. Periodic removal of the infiltrating water is assumed to have flushed some of the activity from the sand. Modeling by LMITCO engineering personnel has quantified (see Attachment V) the extent of the decontamination. The residual activity for these species is added to their respective tanks. The modeling effort included only those nuclides and species identified by Annette Schafer as Potential Contaminants of Concern.
11. The residual liquid heel is jet pumped to 400 gallons at the time of grouting. This assumes that grout can be placed such that the liquid heel will be moved toward the installed jet pump. The jet pump is assumed to plug off leaving a 400 gallon heel.

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### Tank Farm Estimated Residuals

Bulk species

|                 | Units | WM-180  | WM-181  | WM-182  | WM-183  | WM-184  | WM-185  | WM-186  | WM-187  | WM-188  | WM-189  | WM-190  |
|-----------------|-------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| H <sup>+</sup>  | M     | 1.0E-02 |
| Al              | kg    | 2.3E-01 | 5.0E-02 | 6.1E-01 | 1.3E-01 | 7.7E-01 | 1.1E+02 | 9.6E-02 | 9.8E+01 | 1.3E-01 | 1.6E-01 |         |
| B               | kg    | 1.4E-03 | 1.4E-03 | 1.8E-03 | 1.1E-03 | 2.7E-03 | 1.8E-03 | 2.2E-03 | 1.0E-03 | 2.3E-03 | 1.7E-03 |         |
| Cd              | kg    | 1.2E-03 | 4.9E-03 | 4.2E-03 | 1.2E-03 | 7.9E-04 | 2.1E-03 | 1.9E-03 | 4.4E-03 | 5.8E-03 | 3.9E-03 |         |
| Ca              | kg    | 1.1E-01 | 8.9E-02 |         | 7.9E-02 | 9.3E-02 | 1.6E-01 | 1.5E-01 | 7.9E-02 | 2.0E-01 | 1.3E-01 |         |
| Cl              | kg    | 1.5E-02 | 3.6E-03 | 6.6E-03 | 3.1E-03 | 5.4E-02 | 1.1E-02 | 7.2E-03 | 6.0E-04 | 3.0E-03 | 4.5E-03 | 9.1E-03 |
| Cr              | kg    | 2.6E-03 | 1.3E-03 | 5.8E-04 | 6.5E-03 | 3.8E-03 | 2.5E-03 |         | 9.4E-04 | 3.8E-03 | 1.8E-03 |         |
| F               | kg    | 1.1E-03 | 1.4E-02 | 2.8E-02 | 7.9E-03 | 2.7E-02 | 3.0E-02 | 7.7E-03 | 3.4E-02 | 3.3E-02 | 3.8E-02 | 1.1E-01 |
| Fe              | kg    | 1.3E-02 | 5.6E-03 | 2.1E-02 | 2.5E-02 | 3.9E-02 | 1.4E+00 | 1.0E-02 | 8.5E-03 | 1.7E-02 | 1.1E-02 |         |
| K               | kg    | 9.3E-02 | 4.6E-02 | 2.2E-03 | 2.9E-02 | 1.8E-01 | 7.4E-02 | 6.4E-02 | 6.0E-03 | 3.2E-02 | 3.4E-02 |         |
| Mn              | kg    |         | 6.0E-03 |         | 5.6E-03 | 1.6E-02 | 1.0E-02 |         |         |         |         |         |
| Hg              | kg    | 7.9E+00 | 7.9E+00 | 7.9E+00 | 7.9E+00 | 7.9E+00 | 2.3E+01 | 7.9E+00 | 2.1E+01 | 7.9E+00 | 7.9E+00 | 7.9E+00 |
| Mo              | kg    |         |         | 4.2E-04 |         | 5.2E-04 | 1.7E-03 | 1.4E-01 |         |         |         |         |
| Na              | kg    | 6.1E-01 | 1.7E-01 | 8.6E-03 | 1.4E-01 | 1.6E+00 | 2.4E+00 | 2.2E-01 | 2.1E+00 | 9.7E-02 | 1.5E-01 |         |
| Ni              | kg    | 1.2E-03 | 5.9E-04 |         | 3.1E-03 | 2.5E-03 | 8.7E-04 |         |         | 1.8E-03 |         |         |
| NO <sub>3</sub> | kg    | 3.8E+00 | 1.9E+00 | 4.7E+00 | 2.5E+00 | 1.0E+01 | 3.1E+00 | 1.8E+00 | 1.6E+00 | 2.1E+00 | 2.3E+00 | 3.4E-01 |
| Pb              | kg    | 3.9E-03 | 1.7E-03 |         | 2.4E-03 | 8.0E-03 | 1.9E-03 |         |         | 1.4E-03 |         |         |
| PO <sub>4</sub> | kg    |         | 4.9E-03 |         |         | 8.0E-02 | 2.4E-03 |         |         | 1.9E-04 |         |         |
| SO <sub>4</sub> | kg    | 4.1E-01 | 1.9E-02 | 5.0E-02 | 5.0E-02 | 2.4E-01 | 4.1E-02 | 3.2E-02 | 7.7E-03 | 1.9E-02 | 1.7E-02 |         |
| Zr              | kg    | 1.4E-03 | 3.5E-03 | 1.7E-02 | 1.1E-03 |         | 8.7E-03 |         | 1.7E-02 | 1.3E-02 | 1.7E-02 |         |

| Tank Farm Estimated Residuals                  |       |         |         |         |         |         |         |         |         |         |         |         |
|--|-------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Fission and Activation Species decayed to 2016 |       |         |         |         |         |         |         |         |         |         |         |         |
|  | Units | WM-180  | WM-181  | WM-182  | WM-183  | WM-184  | WM-185  | WM-186  | WM-187  | WM-188  | WM-189  | WM-190  |
| Li   | kg    | 6.1E-08 | 6.1E-08 | 6.1E-08 | 6.1E-08 | 6.1E-08 | 8.4E-08 | 6.1E-08 | 7.2E-08 | 6.1E-08 | 6.1E-08 | 6.1E-08 |
| Be   | kg    | 3.3E-08 | 3.3E-08 | 3.3E-08 | 3.3E-08 | 3.3E-08 | 4.2E-08 | 3.3E-08 | 3.7E-08 | 3.3E-08 | 3.3E-08 | 3.3E-08 |
| C  | kg    |         |         |         |         |         | 1.6E-09 |         | 7.8E-10 |         |         |         |
| Zn   | kg    | -       | -       |         |         |         | 3.4E-12 |         | 1.6E-12 |         |         |         |
| Ga   | kg    | 2.9E-10 | 2.9E-10 | 3.0E-10 | 3.0E-10 | 2.9E-10 | 3.3E-10 | 2.9E-10 | 3.1E-10 | 3.0E-10 | 3.0E-10 | 2.9E-10 |
| Ge   | kg    | 1.4E-04 | 1.4E-04 | 1.4E-04 | 1.4E-04 | 1.4E-04 | 1.8E-04 | 1.4E-04 | 1.6E-04 | 1.4E-04 | 1.4E-04 | 1.4E-04 |
| As   | kg    | 4.0E-05 | 4.0E-05 | 4.0E-05 | 4.0E-05 | 4.0E-05 | 5.0E-05 | 4.0E-05 | 4.5E-05 | 4.0E-05 | 4.0E-05 | 4.0E-05 |
| Se   | kg    | 1.4E-02 | 1.4E-02 | 1.4E-02 | 1.4E-02 | 1.4E-02 | 1.8E-02 | 1.4E-02 | 1.6E-02 | 1.4E-02 | 1.4E-02 | 1.4E-02 |
| Br   | kg    | 5.4E-03 | 5.4E-03 | 5.4E-03 | 5.4E-03 | 5.4E-03 | 6.9E-03 | 5.4E-03 | 6.1E-03 | 5.4E-03 | 5.4E-03 | 5.4E-03 |
| Rb   | kg    | 1.1E-01 | 1.1E-01 | 1.1E-01 | 1.1E-01 | 1.1E-01 | 1.4E-01 | 1.1E-01 | 1.2E-01 | 1.1E-01 | 1.1E-01 | 1.1E-01 |
| Sr   | kg    | 1.6E-01 | 1.6E-01 | 1.6E-01 | 1.6E-01 | 1.6E-01 | 2.4E-01 | 1.6E-01 | 2.0E-01 | 1.6E-01 | 1.6E-01 | 1.6E-01 |
| Y  | kg    | 1.4E-01 | 1.4E-01 | 1.4E-01 | 1.4E-01 | 1.3E-01 | 1.4E-01 | 1.4E-01 | 1.4E-01 | 1.4E-01 | 1.4E-01 | 1.3E-01 |
| Zr   | kg    | 8.3E-01 | 8.3E-01 | 8.4E-01 | 8.4E-01 | 8.3E-01 | 1.1E+00 | 8.3E-01 | 9.7E-01 | 8.4E-01 | 8.3E-01 | 8.3E-01 |
| Nb   | kg    | 1.3E-03 |
| Mo   | kg    | 7.6E-01 | 7.6E-01 | 7.7E-01 | 7.7E-01 | 7.6E-01 | 9.8E-01 | 7.6E-01 | 8.6E-01 | 7.7E-01 | 7.6E-01 | 7.6E-01 |
| Tc   | kg    | 1.3E-01 | 1.3E-01 | 1.3E-01 | 1.3E-01 | 1.3E-01 | 1.8E-01 | 1.3E-01 | 1.5E-01 | 1.3E-01 | 1.3E-01 | 1.3E-01 |
| Ru   | kg    | 3.8E-01 | 3.8E-01 | 3.9E-01 | 3.8E-01 | 3.8E-01 | 4.9E-01 | 3.8E-01 | 4.3E-01 | 3.8E-01 | 3.8E-01 | 3.8E-01 |
| Rh   | kg    | 8.3E-02 | 8.3E-02 | 8.4E-02 | 8.4E-02 | 8.3E-02 | 1.1E-01 | 8.3E-02 | 9.7E-02 | 8.4E-02 | 8.3E-02 | 8.3E-02 |
| Pd   | kg    | 8.3E-02 | 8.3E-02 | 8.4E-02 | 8.4E-02 | 8.3E-02 | 1.0E-01 | 8.3E-02 | 9.2E-02 | 8.4E-02 | 8.3E-02 | 8.3E-02 |
| Ag   | kg    | 1.5E-03 | 1.5E-03 | 1.5E-03 | 1.5E-03 | 1.5E-03 | 2.0E-03 | 1.5E-03 | 1.7E-03 | 1.5E-03 | 1.5E-03 | 1.5E-03 |
| Cd   | kg    | 4.5E-03 | 4.5E-03 | 4.6E-03 | 4.5E-03 | 4.5E-03 | 5.6E-03 | 4.5E-03 | 5.0E-03 | 4.5E-03 | 4.5E-03 | 4.5E-03 |
| In   | kg    | 3.5E-04 | 3.5E-04 | 3.5E-04 | 3.5E-04 | 3.5E-04 | 4.9E-04 | 3.5E-04 | 4.1E-04 | 3.5E-04 | 3.5E-04 | 3.5E-04 |
| Sn   | kg    | 8.7E-03 | 8.7E-03 | 8.8E-03 | 8.7E-03 | 8.7E-03 | 1.1E-02 | 8.7E-03 | 9.7E-03 | 8.7E-03 | 8.7E-03 | 8.7E-03 |
| Sb   | kg    | 1.7E-03 | 1.7E-03 | 1.8E-03 | 1.7E-03 | 1.7E-03 | 2.2E-03 | 1.7E-03 | 2.0E-03 | 1.7E-03 | 1.7E-03 | 1.7E-03 |
| Te   | kg    | 8.1E-02 | 8.1E-02 | 8.3E-02 | 8.2E-02 | 8.1E-02 | 1.0E-01 | 8.1E-02 | 9.2E-02 | 8.2E-02 | 8.2E-02 | 8.1E-02 |
| I  | kg    | 1.0E+01 |
| Cs   | kg    | 5.2E-01 | 5.2E-01 | 5.3E-01 | 5.2E-01 | 5.2E-01 | 6.4E-01 | 5.2E-01 | 5.3E-01 | 5.2E-01 | 5.2E-01 | 5.2E-01 |
| Ba   | kg    | 5.0E-01 | 5.0E-01 | 5.1E-01 | 5.0E-01 | 5.0E-01 | 6.5E-01 | 5.0E-01 | 5.7E-01 | 5.1E-01 | 5.0E-01 | 5.0E-01 |
| La   | kg    | 2.8E-01 | 2.8E-01 | 2.8E-01 | 2.8E-01 | 2.8E-01 | 3.6E-01 | 2.8E-01 | 3.2E-01 | 2.8E-01 | 2.8E-01 | 2.8E-01 |
| Ce   | kg    | 5.5E-01 | 5.5E-01 | 5.6E-01 | 5.6E-01 | 5.5E-01 | 7.1E-01 | 5.5E-01 | 6.3E-01 | 5.6E-01 | 5.6E-01 | 5.5E-01 |
| Pr   | kg    | 2.6E-01 | 2.6E-01 | 2.6E-01 | 2.6E-01 | 2.6E-01 | 3.3E-01 | 2.6E-01 | 3.0E-01 | 2.6E-01 | 2.6E-01 | 2.6E-01 |
| Nd   | kg    | 9.5E-01 | 9.5E-01 | 9.7E-01 | 9.6E-01 | 9.5E-01 | 1.2E+00 | 9.5E-01 | 1.1E+00 | 9.6E-01 | 9.6E-01 | 9.5E-01 |
| Prm  | kg    | 1.3E-06 |
| Sm   | kg    | 1.9E-01 | 1.9E-01 | 1.9E-01 | 1.9E-01 | 1.9E-01 | 2.5E-01 | 1.9E-01 | 2.2E-01 | 1.9E-01 | 1.9E-01 | 1.9E-01 |
| Eu   | kg    | 1.7E-02 | 1.7E-02 | 1.7E-02 | 1.7E-02 | 1.7E-02 | 2.1E-02 | 1.7E-02 | 1.9E-02 | 1.7E-02 | 1.7E-02 | 1.7E-02 |
| Gd   | kg    | 9.0E-03 | 9.0E-03 | 9.1E-03 | 9.0E-03 | 9.0E-03 | 1.0E-02 | 9.0E-03 | 9.6E-03 | 9.1E-03 | 9.0E-03 | 9.0E-03 |
| Tb   | kg    | 7.4E-05 | 7.4E-05 | 7.6E-05 | 7.5E-05 | 7.4E-05 | 9.4E-05 | 7.4E-05 | 8.4E-05 | 7.5E-05 | 7.5E-05 | 7.4E-05 |
| Dy   | kg    | 2.3E-05 | 2.3E-05 | 2.3E-05 | 2.3E-05 | 2.2E-05 | 2.7E-05 | 2.3E-05 | 2.5E-05 | 2.3E-05 | 2.3E-05 | 2.2E-05 |
| Ho   | kg    | 9.7E-07 | 9.7E-07 | 9.8E-07 | 9.7E-07 | 9.7E-07 | 1.1E-06 | 9.7E-07 | 1.0E-06 | 9.8E-07 | 9.7E-07 | 9.7E-07 |
| Er   | kg    | 3.8E-07 | 3.8E-07 | 3.9E-07 | 3.8E-07 | 3.8E-07 | 4.5E-07 | 3.8E-07 | 4.1E-07 | 3.8E-07 | 3.8E-07 | 3.8E-07 |
| Tm   | kg    | 1.9E-10 | 1.9E-10 | 1.9E-10 | 1.9E-10 | 1.9E-10 | 2.0E-10 | 1.9E-10 | 1.9E-10 | 1.9E-10 | 1.9E-10 | 1.9E-10 |
| Yb   | kg    | 3.3E-11 |
| Tl   | kg    | 2.3E-15 | 2.3E-15 | 2.3E-15 | 2.3E-15 | 2.2E-15 | 2.3E-15 | 2.3E-15 | 2.3E-15 | 2.3E-15 | 2.3E-15 | 2.2E-15 |
| Pb   | kg    | 3.3E-08 | 3.3E-08 | 3.3E-08 | 3.3E-08 | 3.3E-08 | 3.4E-08 | 3.3E-08 | 3.4E-08 | 3.3E-08 | 3.3E-08 | 3.3E-08 |
| Bi   | kg    | 6.6E-13 | 6.6E-13 | 6.7E-13 | 6.6E-13 | 6.6E-13 | 8.6E-13 | 6.6E-13 | 7.6E-13 | 6.6E-13 | 6.6E-13 | 6.6E-13 |
| Po   | kg    | 2.6E-13 | 2.6E-13 | 2.6E-13 | 2.6E-13 | 2.6E-13 | 7.4E-13 | 2.6E-13 | 4.9E-13 | 2.6E-13 | 2.6E-13 | 2.6E-13 |
| At   | kg    | 2.6E-23 | 2.6E-23 | 2.6E-23 | 2.6E-23 | 2.6E-23 | 3.3E-23 | 2.6E-23 | 2.9E-23 | 2.6E-23 | 2.6E-23 | 2.6E-23 |
| Fr   | kg    | 4.2E-18 | 4.2E-18 | 4.2E-18 | 4.2E-18 | 4.2E-18 | 8.4E-18 | 4.2E-18 | 6.2E-18 | 4.2E-18 | 4.2E-18 | 4.2E-18 |
| Ra   | kg    | 2.8E-09 | 2.8E-09 | 2.8E-09 | 2.8E-09 | 2.8E-09 | 7.4E-09 | 2.8E-09 | 5.0E-09 | 2.8E-09 | 2.8E-09 | 2.8E-09 |
| Ac   | kg    | 1.5E-10 | 1.5E-10 | 1.6E-10 | 1.5E-10 | 1.5E-10 | 3.2E-10 | 1.5E-10 | 2.3E-10 | 1.6E-10 | 1.5E-10 | 1.5E-10 |
| Th   | kg    | 1.1E-05 | 1.1E-05 | 1.1E-05 | 1.1E-05 | 1.1E-05 | 2.3E-05 | 1.1E-05 | 1.7E-05 | 1.1E-05 | 1.1E-05 | 1.1E-05 |
| Pa   | kg    | 3.8E-07 | 3.8E-07 | 3.9E-07 | 3.8E-07 | 3.8E-07 | 7.1E-07 | 3.8E-07 | 5.4E-07 | 3.8E-07 | 3.8E-07 | 3.8E-07 |
| U  | kg    | 1.5E+01 | 1.5E+01 | 1.6E+01 | 1.5E+01 | 1.5E+01 | 1.5E+01 | 1.5E+01 | 1.5E+01 | 1.6E+01 | 1.5E+01 | 1.5E+01 |
| Np   | kg    | 9.2E-03 | 9.2E-03 | 9.3E-03 | 9.2E-03 | 9.2E-03 | 1.3E-02 | 9.2E-03 | 1.1E-02 | 9.3E-03 | 9.2E-03 | 9.2E-03 |
| Pu   | kg    | 2.1E-01 |
| Am   | kg    | 3.3E-03 | 3.3E-03 | 3.3E-03 | 3.3E-03 | 3.3E-03 | 3.4E-03 | 3.3E-03 | 3.3E-03 | 3.3E-03 | 3.3E-03 | 3.3E-03 |
| Cm   | kg    | 3.3E-06 |
| Cf   | kg    | 9.3E-16 | 9.3E-16 | 9.3E-16 | 9.4E-16 | 9.3E-16 | 9.4E-16 | 9.3E-16 | 9.4E-16 | 9.4E-16 | 9.4E-16 | 9.3E-16 |

### Tank Farm Estimated Residuals

Radionuclides decayed to 2016

|        | Units | WM-180  | WM-181  | WM-182  | WM-183  | WM-184  | WM-185  | WM-186  | WM-187  | WM-188  | WM-189  | WM-190  |
|--------|-------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| H 3    | Ci    | 1.1E+00 | 1.1E+00 | 1.2E+00 | 1.1E+00 | 1.1E+00 | 2.3E+00 | 1.1E+00 | 1.7E+00 | 1.1E+00 | 1.1E+00 | 1.1E+00 |
| Be 10  | Ci    | 6.4E-07 | 6.4E-07 | 6.5E-07 | 6.4E-07 | 6.4E-07 | 8.2E-07 | 6.4E-07 | 7.3E-07 | 6.4E-07 | 6.4E-07 | 6.4E-07 |
| C 14   | Ci    | 2.6E-05 | 2.6E-05 | 2.6E-05 | 2.6E-05 | 2.6E-05 | 3.3E-05 | 2.6E-05 | 3.0E-05 | 2.6E-05 | 2.6E-05 | 2.6E-05 |
| Co 60  | Ci    | 1.4E+00 |
| Ni 63  | Ci    | 6.1E+00 |
| Se 79  | Ci    | 9.3E-02 | 9.3E-02 | 9.4E-02 | 9.4E-02 | 9.3E-02 | 1.2E-01 | 9.3E-02 | 1.1E-01 | 9.4E-02 | 9.4E-02 | 9.3E-02 |
| Rb 87  | Ci    | 6.2E-06 | 6.2E-06 | 6.3E-06 | 6.2E-06 | 6.2E-06 | 6.2E-06 | 6.2E-06 | 6.3E-06 | 6.2E-06 | 6.2E-06 | 6.2E-06 |
| Sr 90  | Ci    | 8.1E+03 | 8.1E+03 | 8.2E+03 | 8.2E+03 | 8.1E+03 | 9.8E+03 | 8.1E+03 | 9.5E+03 | 8.2E+03 | 8.2E+03 | 8.1E+03 |
| Y 90   | Ci    | 8.1E+03 | 8.1E+03 | 8.2E+03 | 8.2E+03 | 8.1E+03 | 9.8E+03 | 8.1E+03 | 9.5E+03 | 8.2E+03 | 8.2E+03 | 8.1E+03 |
| Zr 93  | Ci    | 4.7E-01 | 4.7E-01 | 4.7E-01 | 4.7E-01 | 4.7E-01 | 6.0E-01 | 4.7E-01 | 5.3E-01 | 4.7E-01 | 4.7E-01 | 4.7E-01 |
| Nb 93m | Ci    | 4.0E-01 | 4.0E-01 | 4.0E-01 | 4.0E-01 | 4.0E-01 | 5.2E-01 | 4.0E-01 | 4.6E-01 | 4.0E-01 | 4.0E-01 | 4.0E-01 |
| Nb 94  | Ci    | 2.4E-01 |
| Tc 98  | Ci    | 5.5E-07 | 5.5E-07 | 5.6E-07 | 5.5E-07 | 5.5E-07 | 6.0E-07 | 5.5E-07 | 5.7E-07 | 5.6E-07 | 5.6E-07 | 5.5E-07 |
| Tc 99  | Ci    | 2.1E+00 |
| Rh102  | Ci    | 8.3E-06 | 8.3E-06 | 8.4E-06 | 8.3E-06 | 8.3E-06 | 8.3E-06 | 8.3E-06 | 8.3E-06 | 8.4E-06 | 8.3E-06 | 8.3E-06 |
| Ru106  | Ci    | 2.6E-05 |
| Rh106  | Ci    | 2.6E-05 |
| Pd107  | Ci    | 3.5E-03 | 3.5E-03 | 3.5E-03 | 3.5E-03 | 3.5E-03 | 4.5E-03 | 3.5E-03 | 3.9E-03 | 3.5E-03 | 3.5E-03 | 3.5E-03 |
| Ag108  | Ci    |         |         |         |         |         | 6.4E-10 |         | 3.1E-10 |         |         |         |
| Ag108m | Ci    | 8.5E-08 | 8.5E-08 | 8.6E-08 | 8.5E-08 | 8.5E-08 | 9.2E-08 | 8.5E-08 | 8.8E-08 | 8.5E-08 | 8.5E-08 | 8.5E-08 |
| Ag109m | Ci    |         |         |         |         |         | 7.4E-21 |         | 3.6E-21 |         |         |         |
| Cd109  | Ci    |         |         |         |         |         | 7.4E-21 |         | 3.6E-21 |         |         |         |
| Ag110  | Ci    |         |         |         |         |         | 1.3E-26 |         | 6.2E-27 |         |         |         |
| Ag110m | Ci    |         |         |         |         |         | 9.9E-25 |         | 4.7E-25 |         |         |         |
| Cd113m | Ci    | 3.8E-01 | 3.8E-01 | 3.8E-01 | 3.8E-01 | 3.8E-01 | 4.4E-01 | 3.8E-01 | 4.1E-01 | 3.8E-01 | 3.8E-01 | 3.8E-01 |
| In115  | Ci    | 2.1E-11 | 2.1E-11 | 2.1E-11 | 2.1E-11 | 2.1E-11 | 2.2E-11 | 2.1E-11 | 2.1E-11 | 2.1E-11 | 2.1E-11 | 2.1E-11 |
| Sn119m | Ci    | 1.2E-02 |
| Sn121m | Ci    | 1.2E-02 | 1.2E-02 | 1.2E-02 | 1.2E-02 | 1.2E-02 | 1.5E-02 | 1.2E-02 | 1.3E-02 | 1.2E-02 | 1.2E-02 | 1.2E-02 |
| Te123  | Ci    | 8.1E-14 | 8.1E-14 | 8.2E-14 | 8.2E-14 | 8.1E-14 | 8.3E-14 | 8.1E-14 | 8.2E-14 | 8.2E-14 | 8.2E-14 | 8.1E-14 |
| Sb125  | Ci    | 1.1E-01 |
| Te125m | Ci    | 2.6E-02 |
| Sn126  | Ci    | 8.8E-02 | 8.8E-02 | 8.9E-02 | 8.9E-02 | 8.8E-02 | 1.1E-01 | 8.8E-02 | 9.9E-02 | 8.9E-02 | 8.8E-02 | 8.8E-02 |
| Sb126  | Ci    | 1.2E-02 | 1.2E-02 | 1.2E-02 | 1.2E-02 | 1.2E-02 | 1.6E-02 | 1.2E-02 | 1.4E-02 | 1.2E-02 | 1.2E-02 | 1.2E-02 |
| Sb126m | Ci    | 8.8E-02 | 8.8E-02 | 8.9E-02 | 8.9E-02 | 8.8E-02 | 1.1E-01 | 8.8E-02 | 9.9E-02 | 8.9E-02 | 8.8E-02 | 8.8E-02 |
| I129   | Ci    | 1.1E-02 | 1.1E-02 | 1.2E-02 | 1.1E-02 |
| Cs134  | Ci    | 5.7E-02 | 5.7E-02 | 5.8E-02 | 5.7E-02 |
| Cs135  | Ci    | 1.9E-01 | 1.9E-01 | 1.9E-01 | 1.9E-01 | 1.9E-01 | 2.1E-01 | 1.9E-01 | 2.0E-01 | 1.9E-01 | 1.9E-01 | 1.9E-01 |
| Cs137  | Ci    | 8.0E+03 | 9.9E+03 | 8.0E+03 | 8.0E+03 | 8.0E+03 |
| Ba137m | Ci    | 7.6E+03 | 7.6E+03 | 7.7E+03 | 7.6E+03 | 7.6E+03 | 1.0E+04 | 8.0E+03 | 9.9E+03 | 8.0E+03 | 8.0E+03 | 8.0E+03 |
| La138  | Ci    | 4.2E-11 | 4.2E-11 | 4.2E-11 | 4.2E-11 | 4.2E-11 | 5.5E-11 | 4.2E-11 | 4.8E-11 | 4.2E-11 | 4.2E-11 | 4.2E-11 |
| Ce142  | Ci    | 6.4E-06 | 6.4E-06 | 6.5E-06 | 6.4E-06 | 6.4E-06 | 8.2E-06 | 6.4E-06 | 7.3E-06 | 6.4E-06 | 6.4E-06 | 6.4E-06 |
| Ce144  | Ci    | 1.3E-06 |
| Pr144  | Ci    | 1.3E-06 |
| Pr144m | Ci    | 1.5E-08 |
| Nd144  | Ci    | 3.5E-10 | 3.5E-10 | 3.5E-10 | 3.5E-10 | 3.5E-10 | 4.4E-10 | 3.5E-10 | 3.9E-10 | 3.5E-10 | 3.5E-10 | 3.5E-10 |
| Pm146  | Ci    | 2.1E-03 |
| Sm146  | Ci    | 5.9E-08 | 5.9E-08 | 5.9E-08 | 5.9E-08 | 5.9E-08 | 6.1E-08 | 5.9E-08 | 6.0E-08 | 5.9E-08 | 5.9E-08 | 5.9E-08 |
| Pm147  | Ci    | 1.2E+00 |
| Sm147  | Ci    | 1.6E-06 | 1.6E-06 | 1.6E-06 | 1.6E-06 | 1.6E-06 | 2.2E-06 | 1.6E-06 | 1.9E-06 | 1.6E-06 | 1.6E-06 | 1.6E-06 |
| Sm148  | Ci    | 8.1E-12 | 8.1E-12 | 8.2E-12 | 8.2E-12 | 8.1E-12 | 8.3E-12 | 8.1E-12 | 8.4E-12 | 8.2E-12 | 8.2E-12 | 8.1E-12 |
| Sm149  | Ci    | 8.2E-13 | 8.2E-13 | 8.3E-13 | 8.2E-13 | 8.2E-13 | 1.1E-12 | 8.2E-13 | 9.5E-13 | 8.3E-13 | 8.2E-13 | 8.2E-13 |
| Eu150  | Ci    | 2.5E-06 |
| Sm151  | Ci    | 7.8E+01 | 7.8E+01 | 7.9E+01 | 7.8E+01 | 7.8E+01 | 1.1E+02 | 7.8E+01 | 9.5E+01 | 7.9E+01 | 7.8E+01 | 7.8E+01 |

### Tank Farm Estimated Residuals

Radionuclides decayed to 2016

|        | Units | WM-180  | WM-181  | WM-182  | WM-183  | WM-184  | WM-185  | WM-186  | WM-187  | WM-188  | WM-189  | WM-190  |
|--------|-------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Eu152  | Ci    | 2.8E-01 | 2.8E-01 | 2.8E-01 | 2.8E-01 | 2.8E-01 | 3.0E-01 | 2.8E-01 | 2.9E-01 | 2.8E-01 | 2.8E-01 | 2.8E-01 |
| Gd152  | Ci    | 3.2E-13 | 3.2E-13 | 3.2E-13 | 3.2E-13 | 3.2E-13 | 3.4E-13 | 3.2E-13 | 3.3E-13 | 3.2E-13 | 3.2E-13 | 3.2E-13 |
| Gd153  | Ci    | 2.2E-27 | 2.2E-27 | 2.3E-27 | 2.3E-27 | 2.2E-27 | 8.7E-27 | 2.2E-27 | 5.3E-27 | 2.3E-27 | 2.3E-27 | 2.2E-27 |
| Eu154  | Ci    | 1.2E+01 | 1.2E+01 | 1.3E+01 | 1.2E+01 | 1.2E+01 | 1.3E+01 | 1.2E+01 | 1.3E+01 | 1.2E+01 | 1.2E+01 | 1.2E+01 |
| Eu155  | Ci    | 5.7E+00 | 5.7E+00 | 5.8E+00 | 5.7E+00 | 5.7E+00 | 5.8E+00 | 5.7E+00 | 5.8E+00 | 5.7E+00 | 5.7E+00 | 5.7E+00 |
| Ho166m | Ci    | 1.0E-05 |
| Tm171  | Ci    | 9.9E-13 | 9.9E-13 | 1.0E-12 | 9.9E-13 |
| Tl207  | Ci    | 1.2E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 | 2.4E-05 | 1.2E-05 | 1.8E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 |
| Tl208  | Ci    | 1.5E-04 |
| Tl209  | Ci    | 1.7E-09 | 1.7E-09 | 1.7E-09 | 1.7E-09 | 1.7E-09 | 2.0E-09 | 1.7E-09 | 1.8E-09 | 1.7E-09 | 1.7E-09 | 1.7E-09 |
| Pb209  | Ci    | 8.3E-08 | 8.3E-08 | 8.4E-08 | 8.3E-08 | 8.3E-08 | 9.4E-08 | 8.3E-08 | 8.8E-08 | 8.4E-08 | 8.3E-08 | 8.3E-08 |
| Pb210  | Ci    | 1.2E-06 | 1.2E-06 | 1.2E-06 | 1.2E-06 | 1.2E-06 | 3.3E-06 | 1.2E-06 | 2.2E-06 | 1.2E-06 | 1.2E-06 | 1.2E-06 |
| Pb211  | Ci    | 1.2E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 | 2.4E-05 | 1.2E-05 | 1.8E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 |
| Pb212  | Ci    | 4.2E-04 |
| Pb214  | Ci    | 2.8E-06 | 2.8E-06 | 2.8E-06 | 2.8E-06 | 2.8E-06 | 7.4E-06 | 2.8E-06 | 5.0E-06 | 2.8E-06 | 2.8E-06 | 2.8E-06 |
| Bi210m | Ci    | 4.7E-20 |
| Bi210  | Ci    | 1.2E-06 | 1.2E-06 | 1.2E-06 | 1.2E-06 | 1.2E-06 | 3.3E-06 | 1.2E-06 | 2.2E-06 | 1.2E-06 | 1.2E-06 | 1.2E-06 |
| Bi211  | Ci    | 1.2E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 | 2.4E-05 | 1.2E-05 | 1.8E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 |
| Bi212  | Ci    | 4.2E-04 |
| Bi213  | Ci    | 8.3E-08 | 8.3E-08 | 8.4E-08 | 8.3E-08 | 8.3E-08 | 9.4E-08 | 8.3E-08 | 8.8E-08 | 8.4E-08 | 8.3E-08 | 8.3E-08 |
| Bi214  | Ci    | 2.8E-06 | 2.8E-06 | 2.8E-06 | 2.8E-06 | 2.8E-06 | 7.4E-06 | 2.8E-06 | 5.0E-06 | 2.8E-06 | 2.8E-06 | 2.8E-06 |
| Po210  | Ci    | 1.2E-06 | 1.2E-06 | 1.2E-06 | 1.2E-06 | 1.2E-06 | 3.3E-06 | 1.2E-06 | 2.2E-06 | 1.2E-06 | 1.2E-06 | 1.2E-06 |
| Po211  | Ci    | 2.6E-04 |
| Po212  | Ci    | 4.2E-04 |
| Po213  | Ci    |         |         |         |         |         | 1.1E-08 |         | 5.2E-09 |         |         |         |
| Po214  | Ci    |         |         |         |         |         | 4.6E-06 |         | 2.2E-06 |         |         |         |
| Po215  | Ci    |         |         |         |         |         | 1.2E-05 |         | 5.7E-06 |         |         |         |
| Po216  | Ci    |         |         |         |         |         | 3.4E-07 |         | 1.6E-07 |         |         |         |
| Po218  | Ci    | 2.8E-06 | 2.8E-06 | 2.8E-06 | 2.8E-06 | 2.8E-06 | 7.4E-06 | 2.8E-06 | 4.4E-06 | 2.8E-06 | 2.8E-06 | 2.8E-06 |
| At217  | Ci    | 8.3E-08 | 8.3E-08 | 8.4E-08 | 8.3E-08 | 8.3E-08 | 9.4E-08 | 8.3E-08 | 7.1E-08 | 8.4E-08 | 8.3E-08 | 8.3E-08 |
| Rn219  | Ci    | 1.2E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 | 2.4E-05 | 1.2E-05 | 1.5E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 |
| Rn220  | Ci    | 4.2E-04 | 3.3E-04 | 4.2E-04 | 4.2E-04 | 4.2E-04 |
| Rn222  | Ci    | 2.8E-06 | 2.8E-06 | 2.8E-06 | 2.8E-06 | 2.8E-06 | 7.4E-06 | 2.8E-06 | 4.4E-06 | 2.8E-06 | 2.8E-06 | 2.8E-06 |
| Fr221  | Ci    | 8.3E-08 | 8.3E-08 | 8.4E-08 | 8.3E-08 | 8.3E-08 | 9.4E-08 | 8.3E-08 | 7.1E-08 | 8.4E-08 | 8.3E-08 | 8.3E-08 |
| Fr223  | Ci    | 1.7E-07 | 1.7E-07 | 1.7E-07 | 1.7E-07 | 1.7E-07 | 3.3E-07 | 1.7E-07 | 2.1E-07 | 1.7E-07 | 1.7E-07 | 1.7E-07 |
| Ra223  | Ci    | 1.2E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 | 2.4E-05 | 1.2E-05 | 1.5E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 |
| Ra224  | Ci    | 4.2E-04 | 3.3E-04 | 4.2E-04 | 4.2E-04 | 4.2E-04 |
| Ra225  | Ci    | 8.3E-08 | 8.3E-08 | 8.4E-08 | 8.3E-08 | 8.3E-08 | 1.0E-07 | 8.3E-08 | 7.8E-08 | 8.4E-08 | 8.3E-08 | 8.3E-08 |
| Ra226  | Ci    | 2.8E-06 | 2.8E-06 | 2.8E-06 | 2.8E-06 | 2.8E-06 | 9.9E-06 | 2.8E-06 | 7.3E-06 | 2.8E-06 | 2.8E-06 | 2.8E-06 |
| Ra228  | Ci    | 1.4E-10 | 1.4E-10 | 1.4E-10 | 1.4E-10 | 1.4E-10 | 1.9E-10 | 1.4E-10 | 1.4E-10 | 1.4E-10 | 1.4E-10 | 1.4E-10 |
| Ac225  | Ci    | 8.3E-08 | 8.3E-08 | 8.4E-08 | 8.3E-08 | 8.3E-08 | 1.0E-07 | 8.3E-08 | 7.1E-08 | 8.4E-08 | 8.3E-08 | 8.3E-08 |
| Ac227  | Ci    | 1.2E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 | 2.4E-05 | 1.2E-05 | 1.5E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 |
| Ac228  | Ci    | 1.4E-10 | 1.4E-10 | 1.5E-10 | 1.4E-10 | 1.4E-10 | 1.9E-10 | 1.4E-10 | 1.4E-10 | 1.4E-10 | 1.4E-10 | 1.4E-10 |
| Th227  | Ci    | 1.2E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 | 2.3E-05 | 1.2E-05 | 1.5E-05 | 1.2E-05 | 1.2E-05 | 1.2E-05 |
| Th228  | Ci    | 4.2E-04 | 3.3E-04 | 4.2E-04 | 4.2E-04 | 4.2E-04 |
| Th229  | Ci    | 8.3E-08 | 8.3E-08 | 8.4E-08 | 8.3E-08 | 8.3E-08 | 1.0E-07 | 8.3E-08 | 7.8E-08 | 8.4E-08 | 8.3E-08 | 8.3E-08 |
| Th230  | Ci    | 1.9E-04 | 1.9E-04 | 1.9E-04 | 1.9E-04 | 1.9E-04 | 5.7E-04 | 1.9E-04 | 4.2E-04 | 1.9E-04 | 1.9E-04 | 1.9E-04 |
| Th231  | Ci    | 4.5E-03 | 4.5E-03 | 4.5E-03 | 4.5E-03 | 4.5E-03 | 4.6E-03 | 4.5E-03 | 3.6E-03 | 4.5E-03 | 4.5E-03 | 4.5E-03 |
| Th232  | Ci    | 1.6E-10 | 1.6E-10 | 1.6E-10 | 1.6E-10 | 1.6E-10 | 2.0E-10 | 1.6E-10 | 1.5E-10 | 1.6E-10 | 1.6E-10 | 1.6E-10 |
| Th234  | Ci    | 4.5E-03 | 3.6E-03 | 4.5E-03 | 4.5E-03 | 4.5E-03 |
| Pa231  | Ci    | 2.1E-05 | 2.1E-05 | 2.1E-05 | 2.1E-05 | 2.1E-05 | 3.7E-05 | 2.1E-05 | 2.4E-05 | 2.1E-05 | 2.1E-05 | 2.1E-05 |
| Pa233  | Ci    | 6.2E-01 | 6.2E-01 | 6.3E-01 | 6.3E-01 | 6.2E-01 | 6.3E-01 | 6.2E-01 | 5.0E-01 | 6.3E-01 | 6.2E-01 | 6.2E-01 |
| Pa234m | Ci    | 4.5E-03 | 3.6E-03 | 4.5E-03 | 4.5E-03 | 4.5E-03 |

### Tank Farm Estimated Residuals

Radionuclides decayed to 2016

|        | Units | WM-180  | WM-181  | WM-182  | WM-183  | WM-184  | WM-185  | WM-186  | WM-187  | WM-188  | WM-189  | WM-190  |
|--------|-------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Pa234  | Ci    | 5.7E-06 | 5.7E-06 | 5.8E-06 | 5.7E-06 | 5.7E-06 | 5.7E-06 | 5.7E-06 | 4.5E-06 | 5.7E-06 | 5.7E-06 | 5.7E-06 |
| U232   | Ci    | 4.0E-04 | 3.2E-04 | 4.0E-04 | 4.0E-04 | 4.0E-04 |
| U233   | Ci    | 5.2E-05 | 4.2E-05 | 5.2E-05 | 5.2E-05 | 5.2E-05 |
| U234   | Ci    | 1.7E-01 | 1.7E-01 | 1.7E-01 | 1.7E-01 | 1.7E-01 | 1.8E-01 | 1.7E-01 | 1.4E-01 | 1.7E-01 | 1.7E-01 | 1.7E-01 |
| U235   | Ci    | 4.5E-03 | 4.5E-03 | 4.5E-03 | 4.5E-03 | 4.5E-03 | 4.6E-03 | 4.5E-03 | 3.6E-03 | 4.5E-03 | 4.5E-03 | 4.5E-03 |
| U236   | Ci    | 7.1E-03 | 7.1E-03 | 7.2E-03 | 7.1E-03 | 7.1E-03 | 7.2E-03 | 7.1E-03 | 5.7E-03 | 7.1E-03 | 7.1E-03 | 7.1E-03 |
| U237   | Ci    | 7.4E-04 | 7.4E-04 | 7.5E-04 | 7.5E-04 | 7.4E-04 | 7.6E-04 | 7.4E-04 | 6.0E-04 | 7.5E-04 | 7.5E-04 | 7.4E-04 |
| U238   | Ci    | 4.5E-03 | 3.6E-03 | 4.5E-03 | 4.5E-03 | 4.5E-03 |
| U240   | Ci    | 1.5E-10 | 1.2E-10 | 1.5E-10 | 1.5E-10 | 1.5E-10 |
| Np235  | Ci    |         |         |         |         |         | 9.9E-21 |         | 4.7E-21 |         |         |         |
| Np237  | Ci    | 1.2E-02 | 1.2E-02 | 1.8E-02 | 1.4E-02 | 1.2E-02 | 1.5E-02 | 1.2E-02 | 1.2E-02 | 1.6E-02 | 1.3E-02 | 1.2E-02 |
| Np238  | Ci    | 1.5E-05 | 1.5E-05 | 1.6E-05 | 1.5E-05 | 1.5E-05 | 1.5E-05 | 1.5E-05 | 1.2E-05 | 1.5E-05 | 1.5E-05 | 1.5E-05 |
| Np239  | Ci    | 4.5E-03 | 3.6E-03 | 4.5E-03 | 4.5E-03 | 4.5E-03 |
| Np240m | Ci    |         |         |         |         |         | 1.1E-13 |         | 5.2E-14 |         |         |         |
| Pu236  | Ci    | 2.4E-05 | 1.9E-05 | 2.4E-05 | 2.4E-05 | 2.4E-05 |
| Pu238  | Ci    | 2.7E+01 | 2.7E+01 | 2.8E+01 | 2.8E+01 | 2.7E+01 | 2.9E+01 | 2.7E+01 | 2.3E+01 | 2.8E+01 | 2.8E+01 | 2.7E+01 |
| Pu239  | Ci    | 1.8E+00 | 1.8E+00 | 1.9E+00 | 1.8E+00 | 1.8E+00 | 1.9E+00 | 1.8E+00 | 1.5E+00 | 1.9E+00 | 1.8E+00 | 1.8E+00 |
| Pu240  | Ci    | 2.2E+00 | 2.2E+00 | 2.3E+00 | 2.3E+00 | 2.2E+00 | 2.3E+00 | 2.2E+00 | 1.8E+00 | 2.3E+00 | 2.3E+00 | 2.2E+00 |
| Pu241  | Ci    | 2.9E+01 | 2.9E+01 | 3.0E+01 | 3.0E+01 | 2.9E+01 | 3.0E+01 | 2.9E+01 | 2.4E+01 | 3.0E+01 | 2.9E+01 | 2.9E+01 |
| Pu242  | Ci    | 1.7E-03 | 1.4E-03 | 1.7E-03 | 1.7E-03 | 1.7E-03 |
| Pu243  | Ci    |         |         |         |         |         | 2.1E-17 |         | 1.0E-17 |         |         |         |
| Pu244  | Ci    | 1.5E-10 | 1.2E-10 | 1.5E-10 | 1.5E-10 | 1.5E-10 |
| Am241  | Ci    | 8.5E-01 | 8.5E-01 | 9.7E-01 | 8.9E-01 | 8.5E-01 | 8.7E-01 | 8.5E-01 | 9.8E-01 | 9.2E-01 | 8.8E-01 | 8.5E-01 |
| Am242m | Ci    | 3.1E-03 | 2.5E-03 | 3.1E-03 | 3.1E-03 | 3.1E-03 |
| Am242  | Ci    | 3.1E-03 | 2.5E-03 | 3.1E-03 | 3.1E-03 | 3.1E-03 |
| Am243  | Ci    | 4.5E-03 | 3.6E-03 | 4.5E-03 | 4.5E-03 | 4.5E-03 |
| Cm242  | Ci    | 2.6E-03 | 2.1E-03 | 2.6E-03 | 2.6E-03 | 2.6E-03 |
| Cm243  | Ci    | 4.5E-03 | 3.6E-03 | 4.5E-03 | 4.5E-03 | 4.5E-03 |
| Cm244  | Ci    | 2.2E-01 | 2.2E-01 | 2.3E-01 | 2.3E-01 | 2.2E-01 | 2.3E-01 | 2.2E-01 | 1.8E-01 | 2.3E-01 | 2.3E-01 | 2.2E-01 |
| Cm245  | Ci    | 6.4E-05 | 6.4E-05 | 6.5E-05 | 6.4E-05 | 6.4E-05 | 6.4E-05 | 6.4E-05 | 5.1E-05 | 6.4E-05 | 6.4E-05 | 6.4E-05 |
| Cm246  | Ci    | 4.2E-06 | 3.3E-06 | 4.2E-06 | 4.2E-06 | 4.2E-06 |
| Cm247  | Ci    | 4.7E-12 | 3.7E-12 | 4.7E-12 | 4.7E-12 | 4.7E-12 |
| Cm248  | Ci    | 5.0E-12 | 5.0E-12 | 5.1E-12 | 5.0E-12 | 5.0E-12 | 5.0E-12 | 5.0E-12 | 4.0E-12 | 5.0E-12 | 5.0E-12 | 5.0E-12 |
| Cf249  | Ci    | 3.6E-12 | 3.6E-12 | 3.7E-12 | 3.6E-12 | 3.6E-12 | 3.6E-12 | 3.6E-12 | 2.9E-12 | 3.7E-12 | 3.6E-12 | 3.6E-12 |
| Cf250  | Ci    | 1.5E-12 | 1.2E-12 | 1.5E-12 | 1.5E-12 | 1.5E-12 |
| Cf251  | Ci    | 5.7E-14 | 5.7E-14 | 5.8E-14 | 5.7E-14 | 5.7E-14 | 5.7E-14 | 5.7E-14 | 4.5E-14 | 5.7E-14 | 5.7E-14 | 5.7E-14 |
| Cf252  | Ci    |         |         |         |         |         | 2.7E-23 |         | 1.3E-23 |         |         |         |

D. J. Harrell  
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April 16, 1999  
Attachment V

Supporting Documentation

- Document 1 Sample Log 990210-4 Partial
- Document 2 Sample Log 990301-6 Partial
- Document 3 WM-185 Sand Support Pad Activity Summary
- Document 4 WM-187 Sand Support Pad Activity Summary
- Document 5 Letter D. R. Wenzel to N. E. Russell, *Calculation of Radionuclide Inventories for Aluminum and Zirconium*, Wen-20-97, dated 14 October 1997.
- Document 6 Letter D. R. Wenzel to N. E. Russell, *Calculation of Radionuclide Inventories for Sodium Bearing Waste*, Wen-23-97, dated 26 November 1997.
- Document 7 Letter D. R. Wenzel to K. N. Brewer, *Calculation of the Mass of Individual Elements in ICPP Wastes from Fission*, Wen-05-98, dated 2 March 1998.
- Document 8 Letter D. R. Wenzel to M. D. Staiger, *Revision of I-129 Activity in Sodium Bearing Waste calculations*, Wen-15-99, 5 March 1999.

D. J. Harrell  
MDS-07-99  
April 16, 1999  
Attachment V  
Document 1

Log Search

Date of Search: 1999-04-16 10:41:00.070

Run by: DAN STAIGER

\*\*\*\*\*  
Search Criteria:

Start Log.....:990210 4

End Log.....:990210 4

Log Approval.:ALL Logs

Result Type...:Entries With Results

-APPROVED only, Not CANCELED

Lab/Group....:ALL Groups

Total # Logs Found...: 1

Total # Results Found: 86

\*\*\*\*\*  
\*\*\*\*\*

| Log #  | Request Name                                       | Log Type   | Charge Num  | Log Approval Info   |
|--|--|--|---|---|
| I  | L  |  |   |   |
| d Sample   | Meth   | a Ana-   |   |   |
| x Name   | #  | b lyst   | Analyte   | ARL   |
|  |  |  |   | Result  |
| 990210-4<br>1 9AH94  | WM:188-1,2,3<br>33993                              | RCRA<br>3 LRH CO60<br>CS134<br>CS137<br>EU154<br>EU155   | A.. 9.03E+03<br>A.. 2.65E+04<br>A.. 1.22E+07<br>A.. 4.78E+04<br>A.. 2.15E+04                        | +- 6.7E+02 d/s/ml<br>+- 1.4E+03 d/s/ml<br>+- 4.6E+05 d/s/ml<br>+- 4.1E+03 d/s/ml<br>+- 2.3E+02 d/s/ml |
| 2 9AH95  | 33993  | 3 LRH CO60<br>CS134<br>CS137<br>EU154<br>EU155   | A.. 9.98E+03<br>A.. 2.73E+04<br>A.. 1.28E+07<br>A.. 5.80E+04<br>A.. 1.677E+04                       | +- 8.7E+02 d/s/ml<br>+- 1.8E+03 d/s/ml<br>+- 4.8E+05 d/s/ml<br>+- 4.1E+03 d/s/ml<br>+- 2.7E+03 d/s/ml |
| 3 9AH96  | 33993  | 3 LRH EU155<br>EU154<br>CS137<br>CS134<br>CO60   | A.. 2.15E+04<br>A.. 4.78E+04<br>A.. 1.217E+07<br>A.. 2.65E+04<br>A.. 9.03E+03                       | +- 2.3E+03 d/s/ml<br>+- 4.1E+03 d/s/ml<br>+- 4.6E+05 d/s/ml<br>+- 1.4E+03 d/s/ml<br>+- 6.7E+02 d/s/ml |
| 7 9AI01  | 53993  | 3 SJH CS137<br>CS134<br>NB94   | A.. 9.85E+07<br>A.. 2.95E+05<br>A.. 3.00E+04  | +- 5.2E+06 d/s/g<br>+- 3.0E+04 d/s/g<br>+- 2.7E+03 d/s/g  |
| 8 9AI02  | 53993  | 3 SJH CS137<br>CS134<br>NB94   | A.. 7.97E+07<br>A.. 2.78E+05<br>A.. 2.34E+05  | +- 4.0E+06 d/s/g<br>+- 1.8E+04 d/s/g<br>+- 1.2E+04 d/s/g  |
| 9 9AI03  | 53993  | 3 SJH CS137<br>CS134<br>NB94<br>CO60   | A.. 1.364E+08<br>A.. 3.93E+05<br>A.. 7.32E+04<br>A.. 2.33E+04                                       | +- 7.2E+06 d/s/g<br>+- 2.9E+04 d/s/g<br>+- 6.0E+03 d/s/g<br>+- 3.0E+03 d/s/g                          |
| 29 9AH95<br>30 9AH96<br>67 9AH94<br>68 9AH95<br>69 9AH96<br>82 9AH94 | 87802<br>87802<br>57171<br>57171<br>57171<br>17093 | 7 RAH MERCURY<br>7 RAH MERCURY<br>7 BET CHLORIDE<br>7 BET CHLORIDE<br>7 BET CHLORIDE<br>7 AWO FLUORIDE | A.. 1.21013E+06<br>A.. 1.21308E+06<br>A.. 4.31E+02<br>A.. 4.48E+02<br>A.. 4.12E+02<br>A.. 3935.0498 | ug/l<br>ug/l<br>ug/mL<br>ug/mL<br>ug/mL<br>mg/l   |

| Log #                   | Request Name | Log Type                          | Charge Num                             | Log Approval Info |
|-------------------------|--------------|-----------------------------------|--|-------------------|
| I<br>d Sample<br>x Name | Meth #       | L<br>a Ana-<br>b lyst Analyte ARL | Result                                 |                   |
| 83 9AH95                | 17093        | 7 AWO FLUORIDE                    | A.. 3806.8074                          | mg/l              |
| 84 9AH96                | 17093        | 7 AWO FLUORIDE                    | A.. 3823.9417                          | mg/l              |
| 94 9AH94                | 47981        | 7 BCS SPGR                        | A.. 1.28583E+00                        | +- 1.9E-04 @ 25/4 |
| 95 9AH95                | 47981        | 7 BCS SPGR                        | A.. 1.28258E+00                        | +- 1.9E-04 @ 25/4 |
| 96 9AH96                | 47981        | 7 BCS SPGR                        | A.. 1.28141E+00                        | +- 1.9E-04 @ 25/4 |
| 97 9AH94                | 57015        | 7 BET ACID                        | A.. 2.42419E+00                        | Normal Acid       |
| 98 9AH95                | 57015        | 7 BET ACID                        | A.. 2.40504E+00                        | Normal Acid       |
| 99 9AH96                | 57015        | 7 BET ACID                        | A.. 2.41411E+00                        | Normal Acid       |
| 100 9AH97               | 18000        | GMH UDS                           | A.. 1.36                               | g/l               |
| 101 9AH98               | 18000        | GMH UDS                           | A.. 0.55                               | g/l               |
| 102 9AH99               | 18000        | GMH UDS                           | A.. 2.46                               | g/l               |
| 103 9AI01               | 18000        | GMH UDS                           | A.. 5.66                               | g/l               |
| 104 9AI02               | 18000        | GMH UDS                           | A.. 6.59                               | g/l               |
| 105 9AI03               | 18000        | GMH UDS                           | A.. 6.10                               | g/l               |
| 106 9AH97               | 18000        | GMH PARTICLE S                    | A.. Unable to determine-unsufficient s |                   |
| 107 9AH98               | 18000        | GMH PARTICLE S                    | A.. Unable to determine-insufficient s |                   |
| 108 9AH99               | 18000        | GMH PARTICLE S                    | A.. Unable to determine-insufficient s |                   |
| 115 9AI01               | 18000        | GMH PARTICLE D                    | A.. See Log 990301-6 for composite res |                   |
| 124 9AH97               | 18000        | GMH SETTLING V                    | A.. Unable to determine - see comment  |                   |
| 125 9AH98               | 18000        | GMH SETTLING V                    | A.. Unable to determine - see comment  |                   |
| 126 9AH99               | 18000        | GMH SETTLING V                    | A.. Unable to determine - see comment  |                   |
| 127 9AI01               | 18000        | GMH SETTLING V                    | A.. Unable to determine - see comment  |                   |
| 128 9AI02               | 18000        | GMH SETTLING V                    | A.. Unable To Determine - See Comment  |                   |
| 129 9AI03               | 18000        | GMH SETTLING V                    | A.. Unable To Determine - See Comments |                   |
| 130 9AH94               | 13201        | 3 IDG AM241                       | A.. 2.65E+03                           | +- 1.7E+02 d/s/ml |
| 132 9AH96               | 13201        | 3 IDG AM241                       | A.. 2.71E+03                           | +- 1.7E+02 d/s/ml |
| 136 9AI01               | 13201        | 3 IDG AM241                       | A.. 5.62E+03                           | +- 7.4E+02 d/s/g  |
| 137 9AI02               | 13201        | 3 IDG AM241                       | A.. 7.96E+03                           | +- 8.7E+02 d/s/g  |
| 138 9AI03               | 13201        | 3 IDG AM241                       | A.. 9.8E+03                            | +- 1.1E+03 d/s/g  |
| 139 9AH94               | 13202        | 3 IDG PU238                       | A.. 4.84E+04                           | +- 2.1E+03 d/s/ml |
|                         |              | PU239                             | A.. 5.16E+03                           | +- 2.6E+02 d/s/ml |
| 140 9AH95               | 13202        | 3 IDG PU238                       | A.. 4.90E+04                           | +- 2.1E+03 d/s/ml |
|                         |              | PU239                             | A.. 5.31E+03                           | +- 2.7E+02 d/s/ml |
| 141 9AH96               | 13202        | 3 IDG PU238                       | A.. 4.63E+04                           | +- 1.9E+03 d/s/ml |
|                         |              | PU239                             | A.. 5.02E+03                           | +- 2.5E+02 d/s/ml |
| 145 9AI01               | 13202        | 3 IDG PU238                       | A.. 2.56E+05                           | +- 1.3E+04 d/s/g  |
|                         |              | PU239                             | A.. 1.23E+04                           | +- 1.2E+03 d/s/g  |
| 146 9AI02               | 13202        | 3 IDG PU238                       | A.. 3.37E+05                           | +- 1.7E+04 d/s/g  |
|                         |              | PU239                             | A.. 1.95E+04                           | +- 1.7E+03 d/s/g  |
| 147 9AI03               | 13202        | 3 IDG PU238                       | A.. 2.46E+05                           | +- 1.4E+04 d/s/g  |
|                         |              | PU239                             | A.. 1.59E+04                           | +- 1.6E+03 d/s/g  |
| 148 9AH94               | 13204        | 3 IDG NP237                       | A.. 2.52E+01                           | +- 2.9E+00 d/s/ml |
| 149 9AH95               | 13204        | 3 IDG NP237                       | A.. 2.63E+01                           | +- 3.1E+00 d/s/ml |
| 150 9AH96               | 13204        | 3 IDG NP237                       | A.. 2.57E+01                           | +- 3.0E+00 d/s/ml |
| 154 9AI01               | 13204        | 3 IDG NP237                       | A.. 1.73E+02                           | +- 4.9E+01 d/s/g  |
| 155 9AI02               | 13204        | 3 IDG NP237                       | A.. 8.3E+01                            | +- 3.2E+01 d/s/g  |
| 156 9AI03               | 13204        | 3 IDG NP237                       | A.. 6.0E+01                            | +- 7.5E+01 d/s/g  |
| 211 9AH94               | 87802        | 7 RAH MERCURY                     | A.. 1.27196E+06                        | ug/l              |
| 212 9AH95               | 87802        | 7 RAH MERCURY                     | A.. 1.23369E+06                        | ug/l              |

| Log #<br>I<br>d Sample<br>x Name | Request Name<br>L | Log Type<br>Meth a Ana-<br># b lyst | Charge Num<br>Analyte ARL | Log Approval Info<br>Result |
|----------------------------------|-------------------|-------------------------------------|---------------------------|-----------------------------|
| 213 9AH96                        | 87802             | 7 RAH MERCURY                       | A..                       | 1.20719E+06 ug/l            |
| 218 9AH94                        | 17802             | 7 JSL MERCURY                       | A..                       | 1.25724E+06 ug/L            |
| 232 9AI01                        | 18000             | GMH % MOISTURE                      | A..                       | 59.08 % Fines Moisture      |
| 233 9AI02                        | 18000             | GMH % MOISTURE                      | A..                       | 55.17 % Fines Moisture      |
| 234 9AI03                        | 18000             | GMH % MOISTUTE                      | A..                       | 56.80 % Fines Moisture      |
| 239 9AH95                        | 13201             | 3 IDG AM241                         | A..                       | 2.95E+03 +- 1.9E+02 d/s/ml  |

\*\*\*\*\* END \*\*\*\*\*

D. J. Harrell  
MDS-07-99  
April 16, 1999  
Attachment V  
Document 2

Log Search  
Date of Search: 1999-04-16 10:42:51.550

Run by: DAN STAIGER

\*\*\*\*\*  
Search Criteria:

Start Log.....:990301 6

End Log.....:990301 6

Log Approval.:ALL Logs

Result Type..:Entries With Results

-APPROVED only, Not CANCELED

Lab/Group....:ALL Groups

Total # Logs Found...: 1

Total # Results Found: 17

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| Log #  | Request Name  | Log Type   | Charge Num   | Log Approval Info      |
|--|---|--|--|------------------------|
| I  | L   |  |  |                        |
| d Sample   | Meth  | a Ana-   |  |                        |
| x Name   | #   | b lyst   | Analyte ARL  | Result                 |
| 990301-6<br>1 9AM73  | WM:188-4<br>53993   | RCRA<br>3 SJH EU155<br>EU154<br>CS137<br>CS134<br>ZR95<br>CO60   | A.. 2.13E+04 +- 3.0E+03 d/s/ml<br>A.. 5.90E+04 +- 6.2E+03 d/s/ml<br>A.. 1.292E+07 +- 5.5E+05 d/s/ml<br>A.. 2.57E+04 +- 1.1E+03 d/s/ml<br>A.. 3.71E+03 +- 3.3E+02 d/s/ml<br>A.. 1.062E+04 +- 7.4E+02 d/s/ml   | 5651TA201 Not Approved |
| 19 9AM73<br>21 9AM73<br>30 9AM73<br>32 9AM74<br>33 9AM75<br>34 9AM74<br>36 9AM74<br>37 9AM75<br>38 9AM74<br>39 9AM75<br>67 9AM75 | 57171<br>17093<br>47981<br>18000<br>18000<br>18000<br>18000<br>18000<br>18000<br>18000<br>18000 | BET CHLORIDE<br>7 AWO FLUORIDE<br>7 BCS SPGR<br>GMH UDS<br>GMH UDS<br>GMH PARTICLE S<br>GMH PARTICLE D<br>GMH BULK DENSI<br>GMH SETTLING V<br>GMH SETTLING V<br>GMH % MOISTURE | A.. 4.03E+02 +- 5.4E+01 ug/mL<br>A.. 3765.084 mg/l<br>A.. 1.27828E+00 +- 1.9E-04 @ 25/4<br>A.. 0.06 g/l<br>A.. 1.09 g/l<br>A.. Unable to determine-insufficient s<br>A.. 1.50 g/cc @ 30 deg. C comp. resul<br>A.. 0.85 g/cc settled; 1.22 g/cc centr<br>A.. Unable to determine - see comment<br>A.. Unable to determine - see comment<br>A.. 84.63 % Fines Moisture |                        |

\*\*\*\*\* END \*\*\*\*\*

D. J. Harrell  
MDS-07-99  
April 16, 1999  
Attachment V  
Document 3

|  |  |            |            |       |  |
|--|--|------------|------------|-------|--|
| Tank WM - 185  |  |            |            |       |  |
| Total Volume of Sand =   | 826                                    | cu.ft.     |            |       |  |
| Interstitial Space =   | 34                                     | %          |            |       |  |
| Interstitial Space =   | 281                                    | cu.ft. =   | 7,951,086  | ml    |  |
| Density of Sand =  | 110                                    | lbs/cu.ft. |            |       |  |
| Mass of Sand =   | 90,860.00                              | lbs =      | 41,250,440 | grams |  |
| Interstitial Liquid Remaining in Sand After Draining =   | 30                                     | %          |            |       |  |
| Interstitial Liquid Remaining in Sand After Draining =   | 84                                     | cu.ft.     |            |       |  |
| Isotope  | Activity Remaining in Sand in 2016, Ci |            |            |       |  |
| Ac-225   | 1.69E-08                               |            |            |       |  |
| Am-241   | 4.15E-01                               |            |            |       |  |
| Cs-137   | 2.70E+03                               |            |            |       |  |
| I-129  | 3.51E-22                               |            |            |       |  |
| Np-237   | 2.14E-03                               |            |            |       |  |
| Pa-233   | 2.14E-03                               |            |            |       |  |
| Pu-238   | 1.19E+00                               |            |            |       |  |
| Pu-239   | 1.50E-01                               |            |            |       |  |
| Pu-240   | 5.99E-02                               |            |            |       |  |
| Ra-225   | 1.70E-08                               |            |            |       |  |
| Ra-226   | 7.17E-06                               |            |            |       |  |
| Sr-90  | 1.67E+03                               |            |            |       |  |
| Tc-99  | 3.68E-07                               |            |            |       |  |
| Th-229   | 1.70E-08                               |            |            |       |  |
| Th-230   | 3.78E-04                               |            |            |       |  |
| U-234  | 5.29E-03                               |            |            |       |  |
| Y-90   | 1.67E+03                               |            |            |       |  |
| Ba-137m  | 2.55E+03                               |            |            |       |  |
| Total Activity   | 8,590                                  |            |            |       |  |
| Notes:   |  |            |            |       |  |
| 1. Y-90 activity essentially reaches the same value as Sr-90 after 30 days, if equilibrium is disturbed. |  |            |            |       |  |
| 2. Ba-137m activity reaches 94% of the value of Cs-137 within a few hours if equilibrium is disturbed.   |  |            |            |       |  |
| Chemical Species   | G-Moles Remaining in Sand in 2016      |            |            |       |  |
| Hg   | 73                                     |            |            |       |  |
| NO <sub>3</sub>  | 0                                      |            |            |       |  |

D. J. Harrell  
MDS-07-99  
April 16, 1999  
Attachment V  
Document 4

|  |  |           |            |            |       |
|--|--|-----------|------------|------------|-------|
| Tank WM - 187  |  |           |            |            |       |
| Total Volume of Sand =   |  | 826       | cu.ft.     |            |       |
| Interstitial Space =   |  | 34        | %          |            |       |
| Interstitial Space =   |  | 281       | cu.ft. =   | 7,951,086  | ml    |
| Density of Sand =  |  | 110       | lbs/cu.ft. |            |       |
| Mass of Sand =   |  | 90,860.00 | lbs =      | 41,250,440 | grams |
| Interstitial Liquid Remaining in Sand<br>After Draining =  |  | 30        | %          |            |       |
| Interstitial Liquid Remaining in Sand<br>After Draining =  |  | 84        | cu.ft.     |            |       |
| Isotope  | Activity<br>Remaining in Sand<br>in 2016, Ci |           |            |            |       |
| Ac-225   | 1.21E-08                                     |           |            |            |       |
| Am-241   | 2.96E-01                                     |           |            |            |       |
| Cs-137   | 1.93E+03                                     |           |            |            |       |
| I-129  | 1.74E-14                                     |           |            |            |       |
| Np-237   | 1.95E-03                                     |           |            |            |       |
| Pa-233   | 1.95E-03                                     |           |            |            |       |
| Pu-238   | 9.25E-01                                     |           |            |            |       |
| Pu-239   | 1.17E-01                                     |           |            |            |       |
| Pu-240   | 4.67E-02                                     |           |            |            |       |
| Ra-225   | 1.21E-08                                     |           |            |            |       |
| Ra-226   | 5.12E-06                                     |           |            |            |       |
| Sr-90  | 1.40E+03                                     |           |            |            |       |
| Tc-99  | 1.44E-04                                     |           |            |            |       |
| Th-229   | 1.21E-08                                     |           |            |            |       |
| Th-230   | 2.70E-04                                     |           |            |            |       |
| U-234  | 5.23E-03                                     |           |            |            |       |
| Y-90   | 1.40E+03                                     |           |            |            |       |
| Ba-137m  | 1.82E+03                                     |           |            |            |       |
| Total Activity   | 6,545  |           |            |            |       |
| Notes:   |  |           |            |            |       |
| 1. Y-90 activity essentially reaches the same value as Sr-90 after 30 days, if equilibrium is disturbed.<br>2. Ba-137m activity reaches 94% of the value of Cs-137 within a few hours if equilibrium is disturbed. |  |           |            |            |       |
| Chemical Species   | G-Moles<br>Remaining in Sand<br>in 2016      |           |            |            |       |
| Hg   | 64   |           |            |            |       |
| NO <sub>3</sub>  | 0  |           |            |            |       |

D. J. Harrell  
MDS-07-99  
April 16, 1999  
Attachment V  
Document 5

**LOCKHEED MARTIN**

Lockheed Idaho Technologies Company

**INTERDEPARTMENTAL COMMUNICATION**

Date: October 14, 1997

To: N. E. Russell, MS 3765

From: D. R. Wenzel, MS 5209

*DRW*

Subject: CALCULATION OF RADIONUCLIDE INVENTORIES FOR ALUMINUM AND ZIRCONIUM - Wen-20-97

Reference: Radiation Shielding Information Center, *RSIC Computer Code Collection*, "ORIGEN2.1, Isotope Generation and Depletion Code Matrix Exponential Method," CCC-371, Oak Ridge, Tennessee, 1991.

The Waste Form and Characterization Scoping Study requires a knowledge of the radionuclide content of calcined waste at the ICPP in order to evaluate treatment options. Routine radiochemical analyses; however, do not identify all of the radionuclides present. Calculations have therefore been made to calculate complete radionuclide inventories for Al and Zr calcines.

Calculations have been based on the best information that could be identified. This information includes the analysis of liquid wastes converted to calcine, analysis of calcine samples, knowledge of the irradiation histories and burnups of fuels processed, and the quantities of fuels processed each year. Calculations were then made using the ORIGEN2 code (Reference) to calculate the activities for radionuclides that could not be established from analytical analyses.

Tables 1 and 2 contain the calculated radionuclide inventories respectively for Al and Zr calcines as a function of decay time. The inventories for Al calcine are representative of the calcine stored in Bin Set #1. The Al calcine in Bin Set #1 came from Al fuels processed at the ICPP between 1958 and 1963. The inventories for Zr calcine are representative of the calcine that was produced following the final Fuel Dissolution Process campaign in 1988. While a rigorous error analysis was not made, the results of the calculations are estimated to have an accuracy of  $\pm$  a factor of 2. The calculated radionuclides inventories are also for average calcine and do not reflect minor variations that should be expected due to stratification of calcine in the storage bins. Also, the actual activities of the shorter-lived radionuclides in actual calcine should be expected to deviate more than a factor of 2 because fuel has been processed intermittently at the ICPP between 1958 and 1988 and the age of the waste in the calcine varies. However, as decay times increase, the amounts of the shorter-lived radionuclides that do not have long-lived parents decay tend to become insignificant.

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While calculations were being made, gamma-ray photon spectrums for both Al and Zr calcines were also calculated. Tables 3 and 4 contain photon spectrums respectively for Al and Zr calcines.

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**Table 1: Calculated Radionuclide Activities for Al Calcine in Ci/g as a Function of Decay Time**

| Nuclide | Half-Life<br>(Actinides and Daughters) | 2016    | 2035    | Decay Time Since 2016 (yr) |         |         |
|---------|--|---------|---------|----------------------------|---------|---------|
|         |  |         |         | 1E2                        | 5E2     | 1E3     |
| Tl207   | 4.770E+00 m                            | 2.4E-11 | 2.7E-11 | 3.1E-11                    | 3.2E-11 | 3.3E-11 |
| Tl208   | 3.053E+00 m                            | 2.5E-13 | 2.1E-13 | 7.9E-14                    | 3.4E-15 | 1.8E-15 |
| Tl209   | 2.200E+00 m                            | 4.8E-16 | 5.1E-16 | 9.6E-16                    | 7.1E-15 | 2.4E-14 |
| Pb209   | 3.253E+00 h                            | 2.2E-14 | 2.4E-14 | 4.4E-14                    | 3.3E-13 | 1.1E-12 |
| Pb210   | 2.226E+01 yr                           | 4.3E-12 | 7.5E-12 | 2.7E-11                    | 1.1E-10 | 2.1E-10 |
| Pb211   | 3.610E+01 m                            | 2.4E-11 | 2.7E-11 | 3.1E-11                    | 3.2E-11 | 3.3E-11 |
| Pb212   | 1.064E+01 h                            | 6.9E-13 | 5.7E-13 | 2.2E-13                    | 9.5E-15 | 5.0E-15 |
| Pb214   | 2.680E+01 m                            | 9.3E-12 | 1.3E-11 | 3.4E-11                    | 1.1E-10 | 2.1E-10 |
| Bi210m  | 3.000E+06 yr                           | 9.1E-29 | 9.1E-29 | 9.1E-29                    | 9.1E-29 | 9.1E-29 |
| Bi210   | 5.013E+00 d                            | 4.3E-12 | 7.5E-12 | 2.7E-11                    | 1.1E-10 | 2.1E-10 |
| Bi211   | 2.130E+00 m                            | 2.4E-11 | 2.7E-11 | 3.1E-11                    | 3.2E-11 | 3.3E-11 |
| Bi212   | 6.055E+01 m                            | 6.9E-13 | 5.7E-13 | 2.2E-13                    | 9.5E-15 | 5.0E-15 |
| Bi213   | 4.565E+01 m                            | 2.2E-14 | 2.4E-14 | 4.4E-14                    | 3.3E-13 | 1.1E-12 |
| Bi214   | 1.990E+01 m                            | 9.3E-12 | 1.3E-11 | 3.4E-11                    | 1.1E-10 | 2.1E-10 |
| Po210   | 1.384E+02 d                            | 4.3E-12 | 7.5E-12 | 2.7E-11                    | 1.1E-10 | 2.1E-10 |
| Po211   | 5.160E-01 s                            | 6.6E-14 | 7.6E-14 | 8.8E-14                    | 9.0E-14 | 9.3E-14 |
| Po212   | 3.000E-07 s                            | 4.4E-13 | 3.7E-13 | 1.4E-13                    | 6.1E-15 | 3.2E-15 |
| Po213   | 4.200E-06 s                            | 2.2E-14 | 2.3E-14 | 4.3E-14                    | 3.2E-13 | 1.1E-12 |
| Po214   | 1.637E-04 s                            | 9.3E-12 | 1.3E-11 | 3.4E-11                    | 1.1E-10 | 2.1E-10 |
| Po215   | 1.778E-03 s                            | 2.4E-11 | 2.7E-11 | 3.1E-11                    | 3.2E-11 | 3.3E-11 |
| Po216   | 1.460E-01 s                            | 6.9E-13 | 5.7E-13 | 2.2E-13                    | 9.5E-15 | 5.0E-15 |
| Po218   | 3.050E+00 m                            | 9.3E-12 | 1.3E-11 | 3.4E-11                    | 1.1E-10 | 2.1E-10 |
| At217   | 3.230E-02 s                            | 2.2E-14 | 2.4E-14 | 4.4E-14                    | 3.3E-13 | 1.1E-12 |
| Rn219   | 3.960E+00 s                            | 2.4E-11 | 2.7E-11 | 3.1E-11                    | 3.2E-11 | 3.3E-11 |
| Rn220   | 5.561E+01 s                            | 6.9E-13 | 5.7E-13 | 2.2E-13                    | 9.5E-15 | 5.0E-15 |
| Rn222   | 3.824E+00 d                            | 9.3E-12 | 1.3E-11 | 3.4E-11                    | 1.1E-10 | 2.1E-10 |
| Fr221   | 4.800E+00 m                            | 2.2E-14 | 2.4E-14 | 4.4E-14                    | 3.3E-13 | 1.1E-12 |
| Fr223   | 2.180E+01 m                            | 3.3E-13 | 3.8E-13 | 4.3E-13                    | 4.5E-13 | 4.6E-13 |
| Ra223   | 1.143E+01 d                            | 2.4E-11 | 2.7E-11 | 3.1E-11                    | 3.2E-11 | 3.3E-11 |
| Ra224   | 3.620E+00 d                            | 6.9E-13 | 5.7E-13 | 2.2E-13                    | 9.5E-15 | 5.0E-15 |
| Ra225   | 1.480E+01 d                            | 2.2E-14 | 2.4E-14 | 4.4E-14                    | 3.3E-13 | 1.1E-12 |
| Ra226   | 1.600E+03 yr                           | 9.3E-12 | 1.3E-11 | 3.4E-11                    | 3.3E-13 | 1.1E-12 |
| Ra228   | 5.750E+00 yr                           | 8.9E-17 | 9.0E-17 | 9.1E-17                    | 1.1E-10 | 2.1E-10 |
| Ac225   | 1.000E+01 d                            | 2.2E-14 | 2.4E-14 | 4.4E-14                    | 3.3E-13 | 1.1E-12 |
| Ac227   | 2.177E+01 yr                           | 2.4E-11 | 2.7E-11 | 3.1E-11                    | 3.2E-11 | 3.3E-11 |
| Ac228   | 6.130E+00 h                            | 8.9E-17 | 9.0E-17 | 9.1E-17                    | 9.6E-17 | 1.0E-16 |
| Th227   | 1.872E+01 d                            | 2.3E-11 | 2.7E-11 | 3.1E-11                    | 3.2E-11 | 3.3E-11 |
| Th228   | 1.913E+00 yr                           | 6.9E-13 | 5.7E-13 | 2.2E-13                    | 9.5E-15 | 5.0E-15 |
| Th229   | 7.340E+03 yr                           | 2.2E-14 | 2.4E-14 | 4.4E-14                    | 3.3E-13 | 1.1E-12 |
| Th230   | 7.700E+04 yr                           | 4.9E-10 | 5.0E-10 | 5.1E-10                    | 5.6E-10 | 6.3E-10 |
| Th231   | 2.552E+01 h                            | 1.0E-10 | 1.0E-10 | 1.0E-10                    | 1.0E-10 | 1.0E-10 |
| Th232   | 1.405E+10 yr                           | 9.0E-17 | 9.0E-17 | 9.1E-17                    | 9.6E-17 | 1.0E-16 |
| Th234   | 2.410E+01 d                            | 5.8E-12 | 5.8E-12 | 5.8E-12                    | 5.8E-12 | 5.8E-12 |
| Pa231   | 3.726E+04 yr                           | 3.2E-11 | 3.2E-11 | 3.2E-11                    | 3.2E-11 | 3.3E-11 |
| Pa233   | 2.700E+01 d                            | 5.0E-09 | 5.0E-09 | 5.0E-09                    | 5.1E-09 | 5.1E-09 |
| Pa234m  | 1.170E+00 m                            | 5.8E-12 | 5.8E-12 | 5.8E-12                    | 5.8E-12 | 5.8E-12 |
| Pa234   | 6.700E+00 h                            | 7.6E-15 | 7.6E-15 | 7.6E-15                    | 7.6E-15 | 7.6E-15 |

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Table 1: Calculated Radionuclide Activities for Al Calcine in Ci/g as a Function of Decay Time (Continued)

| Nuclide                             | <u>Half-Life</u> |    | 2016    | 2035    | Decay Time Since 2016 (yr) |         |         |
|-------------------------------------|------------------|----|---------|---------|----------------------------|---------|---------|
|                                     |                  |    |         |         | 1E2                        | 5E2     | 1E3     |
| (Actinides and Daughters Continued) |                  |    |         |         |                            |         |         |
| U232                                | 7.200E+01        | yr | 6.7E-13 | 5.6E-13 | 2.2E-13                    | 9.3E-15 | 4.9E-15 |
| U233                                | 1.592E+05        | yr | 7.0E-13 | 1.1E-12 | 3.3E-12                    | 1.2E-11 | 2.3E-11 |
| U234                                | 2.445E+05        | yr | 1.5E-08 | 1.5E-08 | 1.5E-08                    | 1.6E-08 | 1.6E-08 |
| U235                                | 7.038E+08        | yr | 1.0E-10 | 1.0E-10 | 1.0E-10                    | 1.0E-10 | 1.0E-10 |
| U236                                | 2.342E+07        | yr | 2.4E-10 | 2.4E-10 | 2.4E-10                    | 2.4E-10 | 2.4E-10 |
| U237                                | 6.750E+00        | d  | 2.1E-11 | 8.3E-12 | 6.7E-14                    | 1.2E-19 | 1.2E-19 |
| U238                                | 4.470E+09        | yr | 5.8E-12 | 5.8E-12 | 5.8E-12                    | 5.8E-12 | 5.8E-12 |
| U240                                | 1.410E+01        | h  | 2.2E-19 | 2.2E-19 | 2.2E-19                    | 2.2E-19 | 2.2E-19 |
| Np235                               | 3.961E+02        | d  | 2.0E-26 |         |                            |         |         |
| Np237                               | 2.140E+06        | yr | 5.0E-09 | 5.0E-09 | 5.0E-09                    | 5.1E-09 | 5.1E-09 |
| Np238                               | 2.117E+00        | d  | 9.1E-14 | 8.3E-14 | 5.3E-14                    | 8.5E-15 | 8.7E-16 |
| Np239                               | 2.355E+00        | d  | 1.9E-11 | 1.9E-11 | 1.9E-11                    | 1.8E-11 | 1.7E-11 |
| Np240m                              | 7.400E+00        | m  | 2.2E-19 | 2.2E-19 | 2.2E-19                    | 2.2E-19 | 2.2E-19 |
| Pu236                               | 2.851E+00        | yr | 5.0E-15 | 4.9E-15 | 4.9E-15                    | 4.9E-15 | 4.9E-15 |
| Pu238                               | 8.775E+01        | yr | 1.9E-06 | 1.6E-06 | 7.3E-07                    | 3.1E-08 | 6.0E-10 |
| Pu239                               | 2.413E+04        | yr | 2.4E-07 | 2.4E-07 | 2.4E-07                    | 2.4E-07 | 2.3E-07 |
| Pu240                               | 6.569E+03        | yr | 9.6E-08 | 9.6E-08 | 9.4E-08                    | 9.1E-08 | 8.6E-08 |
| Pu241                               | 1.440E+01        | yr | 8.4E-07 | 3.4E-07 | 2.7E-09                    | 4.9E-15 | 4.7E-15 |
| Pu242                               | 3.758E+05        | yr | 7.2E-12 | 7.2E-12 | 7.2E-12                    | 7.2E-12 | 7.2E-12 |
| Pu243                               | 4.956E+00        | h  | 4.3E-23 | 4.3E-23 | 4.3E-23                    | 4.3E-23 | 4.3E-23 |
| Pu244                               | 8.260E+07        | yr | 2.2E-19 | 2.2E-19 | 2.2E-19                    | 2.2E-19 | 2.2E-19 |
| Am241                               | 4.322E+02        | yr | 5.4E-07 | 5.4E-07 | 4.7E-07                    | 2.5E-07 | 1.1E-07 |
| Am242m                              | 1.520E+02        | yr | 1.8E-11 | 1.7E-11 | 1.1E-11                    | 1.7E-12 | 1.7E-13 |
| Am242                               | 1.602E+01        | h  | 1.8E-11 | 1.7E-11 | 1.0E-11                    | 1.7E-12 | 1.7E-13 |
| Am243                               | 7.380E+03        | yr | 1.9E-11 | 1.9E-11 | 1.9E-11                    | 1.8E-11 | 1.7E-11 |
| Cm242                               | 1.628E+02        | d  | 1.5E-11 | 1.4E-11 | 8.7E-12                    | 1.4E-12 | 1.4E-13 |
| Cm243                               | 2.850E+01        | yr | 9.7E-13 | 6.1E-13 | 5.4E-14                    | 3.2E-18 | 1.7E-23 |
| Cm244                               | 1.811E+01        | yr | 3.0E-11 | 1.4E-11 | 3.1E-13                    | 7.1E-20 | 3.4E-28 |
| Cm245                               | 8.500E+03        | yr | 5.1E-15 | 5.1E-15 | 5.1E-15                    | 4.9E-15 | 4.7E-15 |
| Cm246                               | 4.750E+03        | yr | 1.2E-16 | 1.2E-16 | 1.2E-16                    | 1.1E-16 | 1.0E-16 |
| Cm247                               | 1.560E+07        | yr | 4.3E-23 | 4.3E-23 | 4.3E-23                    | 4.3E-23 | 4.3E-23 |
| Cm248                               | 3.390E+05        | yr | 1.3E-23 | 1.3E-23 | 1.3E-23                    | 1.3E-23 | 1.3E-23 |
| Cf249                               | 3.506E+02        | yr | 2.6E-23 | 2.5E-23 | 2.1E-23                    | 9.4E-24 | 3.5E-24 |
| Cf250                               | 1.308E+01        | yr | 2.2E-24 | 8.1E-25 | 4.1E-27                    | 2.5E-36 |         |
| Cf251                               | 9.000E+02        | yr | 7.0E-26 | 6.9E-26 | 6.4E-26                    |         |         |
| Cf252                               | 2.639E+00        | yr | 5.5E-29 |         |                            |         |         |
| (Fission Products)                  |                  |    |         |         |                            |         |         |
| H 3                                 | 1.228E+01        | yr | 2.3E-06 | 7.8E-07 | 2.8E-09                    | 5.0E-19 | 3.3E-31 |
| Be 10                               | 1.600E+06        | yr | 3.7E-13 | 3.7E-13 | 3.7E-13                    | 3.7E-13 |         |
| C 14                                | 5.730E+03        | yr | 1.5E-11 | 1.5E-11 | 1.4E-11                    | 1.4E-11 | 1.3E-11 |
| Se 79                               | 6.500E+04        | yr | 5.3E-08 | 5.3E-08 | 5.3E-08                    | 5.3E-08 | 5.3E-08 |
| Sr 90                               | 2.912E+01        | yr | 3.2E-03 | 2.1E-03 | 1.9E-04                    | 1.4E-08 | 9.4E-14 |
| Y 90                                | 6.410E+01        | h  | 3.2E-03 | 2.1E-03 | 1.9E-04                    | 1.4E-08 | 9.4E-14 |
| Zr 93                               | 1.530E+06        | yr | 2.7E-07 | 2.7E-07 | 2.7E-07                    | 2.7E-07 | 2.7E-07 |
| Nb 93m                              | 1.360E+01        | yr | 2.5E-07 | 2.6E-07 | 2.6E-07                    | 2.6E-07 | 2.6E-07 |
| Nb 94                               | 2.030E+04        | yr | 2.9E-12 | 2.9E-12 | 2.8E-12                    | 2.8E-12 | 2.8E-12 |
| Tc 98                               | 4.200E+06        | yr | 8.4E-14 | 8.4E-14 | 8.4E-14                    | 8.4E-14 | 8.4E-14 |
| Tc 99                               | 2.130E+05        | yr | 1.8E-06 | 1.8E-06 | 1.8E-06                    | 1.8E-06 | 1.8E-06 |
| Rh102                               | 2.900E+00        | yr | 1.3E-14 | 1.4E-16 | 5.7E-27                    |         |         |

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Table 1: Calculated Radionuclide Activities for Al Calcine in Ci/g as a Function of Decay Time (Continued)

| <u>Nuclide</u>               | <u>Half-Life</u> | <u>2016</u> | <u>2035</u> | <u>Decay Time Since 2016 (yr)</u> | <u>1E2</u> | <u>5E2</u> | <u>1E3</u> |
|------------------------------|------------------|-------------|-------------|-----------------------------------|------------|------------|------------|
| (Fission Products Continued) |                  |             |             |                                   |            |            |            |
| Tc 99                        | 2.130E+05 yr     | 1.8E-06     | 1.8E-06     | 1.8E-06                           | 1.8E-06    | 1.8E-06    | 1.8E-06    |
| Rh102                        | 2.900E+00 yr     | 1.3E-14     | 1.4E-16     | 5.7E-27                           |            |            |            |
| Ru106                        | 3.682E+02 d      | 2.6E-19     |             |                                   |            |            |            |
| Rh106                        | 2.992E+01 s      | 2.6E-19     |             |                                   |            |            |            |
| Pd107                        | 6.500E+06 yr     | 2.0E-09     | 2.0E-09     | 2.0E-09                           | 2.0E-09    | 2.0E-09    | 2.0E-09    |
| Ag108                        | 2.370E+00 m      | 1.3E-15     | 1.2E-15     | 6.7E-16                           | 7.6E-17    | 4.9E-18    |            |
| Ag108m                       | 1.270E+02 yr     | 1.4E-14     | 1.3E-14     | 7.6E-15                           | 8.5E-16    | 5.6E-17    |            |
| Ag109m                       | 3.960E+01 s      | 1.5E-26     |             |                                   |            |            |            |
| Cd109                        | 4.640E+02 d      | 1.5E-26     |             |                                   |            |            |            |
| Ag110                        | 2.457E+01 s      | 2.6E-32     |             |                                   |            |            |            |
| Ag110m                       | 2.499E+02 d      | 2.0E-30     |             |                                   |            |            |            |
| Cd113m                       | 1.360E+01 yr     | 1.1E-07     | 4.3E-08     | 3.7E-10                           | 2.1E-18    |            |            |
| In115                        | 5.100E+15 yr     | 1.7E-18     | 1.7E-18     | 1.7E-18                           | 1.7E-18    | 1.7E-18    |            |
| Sn119m                       | 2.930E+02 d      | 8.0E-31     | 2.4E-39     |                                   |            |            |            |
| Sn121m                       | 5.000E+01 yr     | 5.2E-09     | 4.0E-09     | 9.9E-10                           | 3.9E-12    | 3.8E-15    |            |
| Te123                        | 1.000E+13 yr     | 3.2E-21     | 3.2E-21     | 3.2E-21                           | 3.2E-21    | 3.2E-21    |            |
| Sb125                        | 2.770E+00 yr     | 5.3E-10     | 4.5E-12     | 6.1E-23                           |            |            |            |
| Te125m                       | 5.800E+01 d      | 1.3E-10     | 1.1E-12     | 1.5E-23                           |            |            |            |
| Sn126                        | 1.000E+05 yr     | 4.7E-08     | 4.7E-08     | 4.7E-08                           | 4.7E-08    | 4.7E-08    |            |
| Sb126                        | 1.240E+01 d      | 6.6E-09     | 6.6E-09     | 6.6E-09                           | 6.6E-09    | 6.6E-09    |            |
| Sb126m                       | 1.900E+01 m      | 4.7E-08     | 4.7E-08     | 4.7E-08                           | 4.7E-08    | 4.7E-08    |            |
| I129                         | 1.570E+07 yr     | 3.0E-09     | 3.0E-09     | 3.0E-09                           | 3.0E-09    | 3.0E-09    |            |
| Cs134                        | 2.062E+00 yr     | 1.8E-11     | 3.1E-14     |                                   |            |            |            |
| Cs135                        | 2.300E+06 yr     | 4.6E-08     | 4.6E-08     | 4.6E-08                           | 4.6E-08    | 4.6E-08    |            |
| Cs137                        | 3.000E+01 yr     | 3.5E-03     | 2.2E-03     | 2.2E-04                           | 2.2E-08    | 2.1E-13    |            |
| Ba137m                       | 2.552E+00 m      | 3.3E-03     | 2.1E-03     | 2.1E-04                           | 2.0E-08    | 2.0E-13    |            |
| La138                        | 1.350E+11 yr     | 2.7E-17     | 2.7E-17     | 2.7E-17                           | 2.7E-17    | 2.7E-17    |            |
| Ce142                        | 1.050E+11 yr     | 3.7E-12     | 3.7E-12     | 3.7E-12                           | 3.7E-12    | 3.7E-12    |            |
| Ce144                        | 2.843E+02 d      | 4.5E-23     |             |                                   |            |            |            |
| Pr144                        | 1.728E+01 m      | 4.5E-23     |             |                                   |            |            |            |
| Pr144m                       | 7.200E+00 m      | 5.4E-25     | 2.4E-32     |                                   |            |            |            |
| Nd144                        | 2.100E+15 yr     | 1.8E-16     | 1.8E-16     | 1.8E-16                           | 1.8E-16    | 1.8E-16    |            |
| Pm146                        | 2.020E+03 d      | 6.3E-11     | 5.8E-12     | 1.9E-17                           |            |            |            |
| Sm146                        | 1.030E+08 yr     | 3.2E-15     | 3.2E-15     | 3.2E-15                           | 3.2E-15    | 3.2E-15    |            |
| Pr147                        | 2.623E+00 yr     | 1.3E-08     | 8.5E-11     | 2.8E-22                           |            |            |            |
| Sm147                        | 1.070E+11 yr     | 1.2E-12     | 1.2E-12     | 1.2E-12                           | 1.2E-12    | 1.2E-12    |            |
| Sm148                        | 8.000E+15 yr     | 1.3E-19     | 1.3E-18     | 1.3E-18                           | 1.3E-18    | 1.3E-18    |            |
| Sm149                        | 1.000E+15 yr     | 5.4E-19     | 5.4E-19     | 5.4E-19                           | 5.4E-19    | 5.4E-19    |            |
| Eu150                        | 3.600E+01 yr     | 1.6E-13     | 1.1E-13     | 1.6E-14                           | 7.4E-18    | 4.9E-22    |            |
| Sm151                        | 9.000E+01 yr     | 7.1E-05     | 6.1E-05     | 2.8E-05                           | 1.3E-06    | 2.8E-08    |            |
| Eu152                        | 1.360E+01 yr     | 3.0E-08     | 1.1E-08     | 7.0E-11                           | 9.8E-20    |            |            |
| Gd152                        | 1.080E+14 yr     | 4.1E-20     | 4.2E-20     | 4.2E-20                           | 4.2E-20    | 4.2E-20    |            |
| Gd153                        | 2.416E+02 d      | 1.3E-32     |             |                                   |            |            |            |
| Eu154                        | 8.600E+00 yr     | 1.6E-06     | 3.5E-07     | 1.1E-10                           | 1.1E-24    |            |            |
| Eu155                        | 4.960E+00 yr     | 9.7E-08     | 6.8E-09     | 5.8E-15                           |            |            |            |
| Ho166Mm                      | 1.200E+03 yr     | 8.9E-13     | 9.8E-13     | 8.3E-13                           | 6.6E-13    | 4.9E-13    |            |
| Tm171                        | 1.920E+00 yr     | 7.3E-24     | 7.7E-27     | 1.6E-42                           |            |            |            |

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Table 2: Calculated Radionuclide Activities for Zr Calcine in Ci/g as a Function of Decay Time

| Nuclide | <u>Half-Life</u><br>(Actinides and Daughters) | <u>Decay Time Since 2016 (yr)</u> |             |            |            |            |
|---------|---|-----------------------------------|-------------|------------|------------|------------|
|         |   | <u>2016</u>                       | <u>2035</u> | <u>1E2</u> | <u>5E2</u> | <u>1E3</u> |
| Tl207   | 4.770E+00 m                                   | 2.0E-12                           | 2.5E-12     | 3.2E-12    | 3.9E-12    | 4.7E-12    |
| Tl208   | 3.053E+00 m                                   | 2.7E-13                           | 2.3E-13     |            |            |            |
| Pb210   | 2.226E+01 yr                                  | 4.1E-15                           | 1.7E-14     | 2.4E-13    | 7.7E-12    | 2.9E-11    |
| Pb211   | 3.610E+01 m                                   | 2.0E-12                           | 2.5E-12     | 3.2E-12    | 3.9E-12    | 4.7E-12    |
| Pb212   | 1.064E+01 h                                   | 7.6E-13                           | 6.3E-13     | 2.9E-13    | 6.2E-15    |            |
| Bi210   | 5.013E+00 d                                   | 4.1E-15                           | 1.7E-14     | 2.4E-13    | 7.7E-12    | 2.9E-11    |
| Bi211   | 2.130E+00 m                                   | 2.0E-12                           | 2.5E-12     | 3.2E-12    | 3.9E-12    | 4.7E-12    |
| Bi212   | 6.055E+01 m                                   | 7.6E-13                           | 6.3E-13     | 2.9E-13    | 6.2E-15    |            |
| Po210   | 1.384E+02 d                                   | 4.1E-15                           | 1.7E-14     | 2.4E-13    | 7.7E-12    | 2.9E-11    |
| Po212   | 3.000E-07 s                                   | 4.9E-13                           | 4.1E-13     | 1.9E-13    | 4.0E-15    | 4.2E-17    |
| Rn220   | 5.561E+01 s                                   | 7.6E-13                           | 6.3E-13     |            |            |            |
| Rn222   | 3.824E+00 d                                   | 1.8E-14                           | 5.0E-14     | 4.0E-13    | 7.7E-12    | 2.9E-11    |
| Ra223   | 1.143E+01 d                                   | 2.0E-12                           | 2.5E-12     | 3.2E-12    | 3.9E-12    | 4.7E-12    |
| Ra224   | 3.620E+00 d                                   | 7.6E-13                           | 6.3E-13     | 2.9E-13    | 6.2E-15    | 6.5E-17    |
| Ra225   | 1.480E+01 d                                   | 1.8E-16                           | 2.9E-16     | 1.4E-15    | 2.6E-14    | 1.1E-13    |
| Ra226   | 1.600E+03 yr                                  | 1.8E-14                           | 5.0E-14     | 4.0E-13    | 7.7E-12    | 2.9E-11    |
| Ra228   | 5.750E+00 yr                                  | 4.6E-18                           | 4.9E-18     | 5.8E-18    | 9.8E-18    | 1.5E-17    |
| Ac225   | 1.000E+01 d                                   | 1.8E-16                           | 2.9E-16     | 1.4E-15    | 2.6E-14    | 1.1E-13    |
| Ac227   | 2.177E+01 yr                                  | 2.0E-12                           | 2.5E-12     | 3.2E-12    | 3.9E-12    | 4.7E-12    |
| Th227   | 1.872E+01 d                                   | 2.0E-12                           | 2.5E-12     | 3.2E-12    | 3.9E-12    | 4.6E-12    |
| Th228   | 1.913E+00 yr                                  | 7.6E-13                           | 6.3E-13     | 2.9E-13    | 6.2E-15    | 6.5E-17    |
| Th229   | 7.340E+03 yr                                  | 1.8E-16                           | 2.9E-16     | 1.4E-15    | 2.6E-14    | 1.1E-13    |
| Th230   | 7.700E+04 yr                                  | 2.9E-12                           | 5.1E-12     | 1.5E-11    | 7.6E-11    | 1.6E-10    |
| Th231   | 2.552E+01 h                                   | 7.6E-11                           | 7.6E-11     | 7.6E-11    | 7.6E-11    | 7.6E-11    |
| Th232   | 1.405E+10 yr                                  | 4.9E-18                           | 5.0E-18     | 5.8E-18    | 9.8E-18    | 1.5E-17    |
| Th234   | 2.410E+01 d                                   | 3.7E-12                           | 3.7E-12     | 3.7E-12    | 3.7E-12    | 3.7E-12    |
| Pa231   | 3.726E+04 yr                                  | 3.2E-12                           | 3.2E-12     | 3.3E-12    | 3.9E-12    | 4.7E-12    |
| Pa233   | 2.700E+01 d                                   | 3.8E-10                           | 3.9E-10     | 4.4E-10    | 5.9E-10    | 6.9E-10    |
| Pa234m  | 1.170E+00 m                                   | 3.7E-12                           | 3.7E-12     | 3.7E-12    | 3.7E-12    | 3.7E-12    |
| Pa234   | 6.700E+00 h                                   | 4.9E-15                           | 4.9E-15     | 4.9E-15    | 4.9E-15    | 4.9E-15    |
| U232    | 7.200E+01 yr                                  | 7.4E-13                           | 6.2E-13     | 2.8E-13    | 6.0E-15    | 4.9E-17    |
| U233    | 1.592E+05 yr                                  | 4.7E-14                           | 7.9E-14     | 2.3E-13    | 1.1E-12    | 2.6E-12    |
| U234    | 2.445E+05 yr                                  | 1.2E-08                           | 1.3E-08     | 1.5E-08    | 1.8E-08    | 1.8E-08    |
| U235    | 7.038E+08 yr                                  | 7.6E-11                           | 7.6E-11     | 7.6E-11    | 7.6E-11    | 7.6E-11    |
| U236    | 2.342E+07 yr                                  | 2.0E-10                           | 2.0E-10     | 2.0E-10    | 2.0E-10    | 2.1E-10    |
| U237    | 6.750E+00 d                                   | 1.7E-10                           | 6.8E-11     | 1.4E-12    |            |            |
| U238    | 4.470E+09 yr                                  | 3.7E-12                           | 3.7E-12     | 3.7E-12    | 3.7E-12    | 3.7E-12    |
| No237   | 2.140E+06 yr                                  | 3.8E-10                           | 3.9E-10     | 4.4E-10    | 5.9E-10    | 6.9E-10    |
| No238   | 2.117E+00 d                                   | 2.3E-15                           | 2.1E-15     | 1.4E-15    | 2.3E-16    |            |
| No239   | 2.355E+00 d                                   | 2.9E-14                           | 2.9E-14     | 2.9E-14    | 2.8E-14    | 2.6E-14    |
| Pu236   | 2.851E+00 yr                                  | 2.4E-14                           | 2.4E-16     |            |            |            |
| Pu238   | 8.775E+01 yr                                  | 1.5E-05                           | 1.3E-05     | 6.9E-06    | 2.9E-07    | 5.7E-09    |
| Pu239   | 2.413E+04 yr                                  | 2.4E-07                           | 2.4E-07     | 2.4E-07    | 2.4E-07    | 2.3E-07    |
| Pu240   | 6.569E+03 yr                                  | 2.2E-07                           | 2.2E-07     | 2.2E-07    | 2.1E-07    | 2.0E-07    |
| Pu241   | 1.440E+01 yr                                  | 7.0E-06                           | 2.8E-06     | 5.6E-08    | 2.5E-16    | 2.2E-18    |
| Pu242   | 3.758E+05 yr                                  | 5.0E-10                           | 5.0E-10     | 5.0E-10    | 5.0E-10    | 5.0E-10    |
| Pu244   | 8.260E+07 yr                                  | 8.6E-23                           | 8.6E-23     | 8.6E-23    | 8.6E-23    | 8.6E-23    |
| Am241   | 4.322E+02 yr                                  | 1.7E-06                           | 1.8E-06     | 1.6E-06    | 8.7E-07    | 3.9E-07    |

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Table 2: Calculated Radionuclide Activities for Zr Calcine in Ci/g as a Function of Decay Time (Continued)

| Nuclide                                    | Half-Life | 2016 | 2035    | Decay Time Since 2016 (yr) |         |         |
|--|-----------|------|---------|----------------------------|---------|---------|
|  |           |      |         | 1E2                        | 5E2     | 1E3     |
| <b>(Actinides and Daughters Continued)</b> |           |      |         |                            |         |         |
| Am242m                                     | 1.520E+02 | yr   | 4.5E-13 | 4.1E-13                    | 2.9E-13 | 4.6E-14 |
| Am242                                      | 1.602E+01 | h    | 4.5E-13 | 4.1E-13                    | 2.8E-13 | 4.6E-14 |
| Am243                                      | 7.380E+03 | yr   | 2.9E-14 | 2.9E-14                    | 2.9E-14 | 2.8E-14 |
| Cm242                                      | 1.628E+02 | d    | 3.7E-13 | 3.4E-13                    | 2.3E-13 | 3.8E-14 |
| Cm243                                      | 2.850E+01 | yr   | 7.3E-15 | 4.6E-15                    | 6.4E-16 | 3.8E-20 |
| Cm244                                      | 1.811E+01 | yr   | 6.5E-14 | 3.1E-14                    | 1.4E-15 |         |
| Cm245                                      | 8.500E+03 | yr   | 2.4E-18 | 2.4E-18                    | 2.3E-18 | 2.2E-18 |
| Cm246                                      | 4.750E+03 | yr   | 3.7E-20 | 3.7E-20                    | 3.5E-20 | 3.2E-20 |
| <b>(Fission Products)</b>                  |           |      |         |                            |         |         |
| H 3  | 1.228E+01 | yr   | 1.3E-06 | 4.4E-07                    | 4.7E-09 | 8.3E-19 |
| Be 10                                      | 1.600E+06 | yr   | 6.3E-14 | 6.3E-14                    | 6.3E-14 | 6.3E-14 |
| C 14                                       | 5.730E+03 | yr   | 2.5E-12 | 2.5E-12                    | 2.5E-12 | 2.3E-12 |
| Se 79                                      | 6.500E+04 | yr   | 9.2E-09 | 9.2E-09                    | 9.2E-09 | 9.1E-09 |
| Rb 87                                      | 4.730E+10 | yr   | 6.2E-13 | 6.2E-13                    | 6.2E-13 | 6.2E-13 |
| Sr 90                                      | 2.912E+01 | yr   | 1.3E-03 | 8.1E-04                    | 1.2E-04 | 8.7E-09 |
| Y 90                                       | 6.410E+01 | h    | 1.3E-03 | 8.1E-04                    | 1.2E-04 | 8.7E-09 |
| Zr 93                                      | 1.530E+06 | yr   | 4.8E-08 | 4.8E-08                    | 4.8E-08 | 4.7E-08 |
| Nb 93m                                     | 1.360E+01 | yr   | 3.8E-08 | 4.2E-08                    | 4.5E-08 | 4.5E-08 |
| Nb 94                                      | 2.030E+04 | yr   | 4.8E-13 | 4.8E-13                    | 4.8E-13 | 4.7E-13 |
| Tc 98                                      | 4.200E+06 | yr   | 7.7E-15 | 7.7E-15                    | 7.7E-15 | 7.7E-15 |
| Tc 99                                      | 2.130E+05 | yr   | 3.1E-07 | 3.1E-07                    | 3.1E-07 | 3.1E-07 |
| Rh102                                      | 2.900E+00 | yr   | 2.7E-13 | 2.9E-15                    |         |         |
| Pd107                                      | 6.500E+06 | yr   | 3.3E-10 | 3.3E-10                    | 3.3E-10 | 3.3E-10 |
| Ag108m                                     | 1.270E+02 | yr   | 6.6E-16 | 5.9E-16                    | 3.8E-16 | 4.3E-17 |
| Cd113m                                     | 1.360E+01 | yr   | 4.7E-08 | 1.9E-08                    | 4.1E-10 | 2.3E-18 |
| In115                                      | 5.100E+15 | yr   | 3.0E-18 | 3.0E-18                    | 3.0E-18 | 3.0E-18 |
| Sn121m                                     | 5.000E+01 | yr   | 1.2E-09 | 9.2E-10                    | 3.0E-10 | 1.2E-12 |
| Te123                                      | 1.000E+13 | yr   | 2.9E-22 | 2.9E-22                    | 2.9E-22 | 2.9E-22 |
| Sb125                                      | 2.770E+00 | yr   | 1.8E-08 | 1.5E-10                    | 2.4E-19 |         |
| Te125m                                     | 5.800E+01 | d    | 4.3E-09 | 3.7E-11                    |         |         |
| Sn126                                      | 1.000E+05 | yr   | 8.1E-09 | 8.1E-09                    | 8.1E-09 | 8.1E-09 |
| Sb126                                      | 1.240E+01 | d    | 1.1E-09 | 1.1E-09                    | 1.1E-09 | 1.1E-09 |
| Sb126m                                     | 1.900E+01 | m    | 8.1E-09 | 8.1E-09                    | 8.1E-09 | 8.1E-09 |
| I129                                       | 1.570E+07 | yr   | 5.1E-10 | 5.1E-10                    | 5.1E-10 | 5.1E-10 |
| Cs134                                      | 2.062E+00 | yr   | 2.9E-09 | 4.8E-12                    |         |         |
| Cs135                                      | 2.300E+06 | yr   | 1.9E-08 | 1.9E-08                    | 1.9E-08 | 1.9E-08 |
| Cs137                                      | 3.000E+01 | yr   | 9.9E-04 | 6.4E-04                    | 9.8E-05 | 9.5E-09 |
| Ba137m                                     | 2.552E+00 | m    | 9.4E-04 | 6.0E-04                    | 9.3E-05 | 9.0E-09 |
| La138                                      | 1.350E+11 | yr   | 4.7E-18 | 4.7E-18                    | 4.7E-18 | 4.7E-18 |
| Ce142                                      | 1.050E+11 | yr   | 6.3E-13 | 6.3E-13                    | 6.3E-13 | 6.3E-13 |
| Nd144                                      | 2.100E+15 | yr   | 3.0E-17 | 3.0E-17                    | 3.0E-17 | 3.0E-17 |
| Pm146                                      | 2.020E+03 | d    | 9.3E-11 | 8.5E-12                    | 3.1E-16 |         |
| Sm146                                      | 1.030E+08 | yr   | 5.6E-16 | 5.6E-16                    | 5.6E-16 | 5.6E-16 |
| Pm147                                      | 2.623E+00 | yr   | 5.9E-07 | 3.9E-09                    | 2.0E-18 |         |
| Sm147                                      | 1.070E+11 | yr   | 2.2E-13 | 2.2E-13                    | 2.2E-13 | 2.2E-13 |
| Sm148                                      | 8.000E+15 | yr   | 2.3E-19 | 2.3E-19                    | 2.3E-19 | 2.3E-19 |
| Sm149                                      | 1.000E+15 | yr   | 9.3E-20 | 9.3E-20                    | 9.3E-20 | 9.3E-20 |

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Table 2: Calculated Radionuclide Activities for Zr Calcine in Ci/g as a Function of Decay Time (Continued)

| Nuclide                             | <u>Half-Life</u> | 2016    | 2035    | <u>Decay Time Since 2016 (yr)</u> |         |         |
|-------------------------------------|------------------|---------|---------|-----------------------------------|---------|---------|
|                                     |                  |         |         | 1E2                               | 5E2     | 1E3     |
| <u>(Fission Products Continued)</u> |                  |         |         |                                   |         |         |
| Eu150                               | 3.600E+01 yr     | 7.3E-14 | 5.1E-14 | 1.1E-14                           | 4.8E-18 | 3.2E-22 |
| Sml51                               | 9.000E+01 yr     | 2.2E-05 | 1.9E-05 | 1.0E-05                           | 4.6E-07 | 9.9E-09 |
| Eu152                               | 1.360E+01 yr     | 4.8E-08 | 1.8E-08 | 2.9E-10                           | 4.1E-19 |         |
| Gd152                               | 1.080E+14 yr     | 2.1E-20 | 2.2E-20 | 2.2E-20                           | 2.2E-20 | 2.2E-20 |
| Eu154                               | 8.600E+00 yr     | 3.9E-06 | 8.4E-07 | 1.2E-09                           |         |         |
| Eu155                               | 4.960E+00 yr     | 5.6E-09 | 3.9E-10 | 4.7E-15                           |         |         |
| Hol66m                              | 1.200E+03 yr     | 8.9E-14 | 8.8E-14 | 8.4E-14                           | 6.7E-14 | 5.0E-14 |
| <u>(Activation Products)</u>        |                  |         |         |                                   |         |         |
| Co 60                               | 5.271E+00 yr     | 5.7E-08 | 4.7E-09 | 1.1E-13                           |         |         |

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Table 3: Calculated Gamma-Ray Photon Spectrum for Al Calcine as a Function of Decay

| Photon Group Energy (MeV) |          |          | Photons/s/g Calcine |         |         |         |         |
|---------------------------|----------|----------|---------------------|---------|---------|---------|---------|
| Lower                     | Upper    | Average  | 2016                | 2035    | 100vr   | 500vr   | 1000vr  |
| 0.00E-0                   | >2.00E-2 | 1.00E-02 | 9.4E+07             | 6.0E+07 | 5.6E+06 | 1.0E+04 | 8.1E+03 |
| 2.00E-2                   | >3.00E-2 | 2.50E-02 | 2.0E+07             | 1.2E+07 | 1.2E+06 | 1.8E+03 | 1.6E+03 |
| 3.00E-2                   | >4.50E-2 | 3.75E-02 | 2.1E+07             | 1.3E+07 | 1.3E+06 | 5.6E+02 | 4.3E+02 |
| 4.50E-2                   | >7.00E-2 | 5.75E-02 | 1.8E+07             | 1.1E+07 | 1.1E+06 | 4.2E+03 | 2.2E+03 |
| 7.00E-2                   | >1.00E-1 | 8.50E-02 | 1.1E+07             | 6.8E+06 | 6.4E+05 | 1.1E+03 | 1.1E+03 |
| 1.00E-1                   | >1.50E-1 | 1.25E-01 | 6.9E+06             | 4.4E+06 | 4.1E+05 | 1.4E+02 | 1.1E+02 |
| 1.50E-1                   | >3.00E-1 | 2.25E-01 | 9.1E+06             | 5.8E+06 | 5.4E+05 | 1.4E+02 | 1.0E+02 |
| 3.00E-1                   | >4.50E-1 | 3.75E-01 | 3.9E+06             | 2.5E+06 | 2.3E+05 | 2.0E+03 | 2.0E+03 |
| 4.50E-1                   | >7.00E-1 | 5.75E-01 | 1.3E+08             | 8.2E+07 | 8.2E+06 | 5.0E+03 | 4.2E+03 |
| 7.00E-1                   | >1.00E+0 | 8.50E-01 | 6.6E+05             | 4.1E+05 | 3.7E+04 | 2.2E+02 | 2.1E+02 |
| 1.00E+0                   | >1.50E+0 | 1.25E+00 | 2.4E+05             | 1.4E+05 | 1.2E+04 | 5.4E+01 | 5.4E+01 |
| 1.50E+0                   | >2.00E+0 | 1.75E+00 | 1.7E+04             | 1.0E+04 | 9.5E+02 | 1.2E+00 | 2.1E+00 |
| 2.00E+0                   | >2.50E+0 | 2.25E+00 | 1.8E+00             | 1.2E+00 | 2.1E-01 | 3.6E-01 | 6.6E-01 |
| 2.50E+0                   | >3.00E+0 | 2.75E+00 | 9.3E-03             | 8.0E-03 | 4.7E-03 | 6.4E-03 | 1.2E-02 |
| 3.00E+0                   | >4.00E+0 | 3.50E+00 | 2.0E-04             | 2.3E-04 | 4.2E-04 | 1.2E-03 | 2.2E-03 |
| 4.00E+0                   | >6.00E+0 | 5.00E+00 | 4.3E-05             | 4.0E-05 | 3.1E-05 | 2.2E-05 | 2.0E-05 |
| 6.00E+0                   | >8.00E+0 | 7.00E+00 | 4.7E-06             | 4.4E-06 | 3.4E-06 | 2.5E-06 | 2.3E-06 |
| 8.00E+0                   | >1.10E+1 | 9.50E+00 | 5.2E-07             | 4.8E-07 | 3.8E-07 | 2.8E-07 | 2.6E-07 |

Table 4: Calculated Gamma-Ray Photon Spectrum for Zr Calcine as a Function of Decay

| Photon Group Energy (MeV) |          |          | Photons/s/g Calcine |         |         |         |         |
|---------------------------|----------|----------|---------------------|---------|---------|---------|---------|
| Lower                     | Upper    | Average  | 2016                | 2035    | 100vr   | 500vr   | 1000vr  |
| 0.00E-0                   | >2.00E-2 | 1.00E-02 | 3.6E+07             | 2.3E+07 | 3.4E+05 | 1.2E+04 | 6.0E+03 |
| 2.00E-2                   | >3.00E-2 | 2.50E-02 | 7.4E+06             | 4.7E+06 | 6.9E+05 | 1.1E+03 | 6.2E+02 |
| 3.00E-2                   | >4.50E-2 | 3.75E-02 | 7.1E+06             | 4.5E+06 | 6.7E+05 | 2.0E+02 | 1.0E+02 |
| 4.50E-2                   | >7.00E-2 | 5.75E-02 | 6.9E+06             | 4.4E+06 | 6.7E+05 | 1.2E+04 | 5.5E+03 |
| 7.00E-2                   | >1.00E-1 | 8.50E-02 | 4.1E+06             | 2.6E+06 | 3.8E+05 | 2.2E+02 | 1.9E+02 |
| 1.00E-1                   | >1.50E-1 | 1.25E-01 | 2.7E+06             | 1.7E+06 | 2.5E+05 | 4.5E+01 | 2.3E+01 |
| 1.50E-1                   | >3.00E-1 | 2.25E-01 | 3.6E+06             | 2.3E+06 | 3.3E+05 | 4.4E+01 | 1.9E+01 |
| 3.00E-1                   | >4.50E-1 | 3.75E-01 | 1.5E+06             | 9.8E+05 | 1.4E+05 | 3.5E+02 | 3.4E+02 |
| 4.50E-1                   | >7.00E-1 | 5.75E-01 | 3.6E+07             | 2.3E+07 | 3.6E+06 | 1.1E+03 | 7.3E+02 |
| 7.00E-1                   | >1.00E+0 | 8.50E-01 | 3.2E+05             | 1.7E+05 | 2.3E+04 | 3.8E+01 | 3.7E+01 |
| 1.00E+0                   | >1.50E+0 | 1.25E+00 | 1.6E+05             | 6.9E+04 | 7.6E+03 | 9.5E+00 | 9.2E+00 |
| 1.50E+0                   | >2.00E+0 | 1.75E+00 | 8.6E+03             | 4.5E+03 | 5.9E+02 | 1.2E-01 | 3.0E-01 |
| 2.00E+0                   | >2.50E+0 | 2.25E+00 | 7.3E-01             | 4.5E-01 | 6.7E-02 | 2.4E-02 | 9.2E-02 |
| 2.50E+0                   | >3.00E+0 | 2.75E+00 | 1.0E-02             | 8.6E-03 | 4.1E-03 | 6.7E-04 | 1.7E-03 |
| 3.00E+0                   | >4.00E+0 | 3.50E+00 | 5.5E-04             | 5.0E-04 | 3.4E-04 | 2.3E-04 | 4.4E-04 |
| 4.00E+0                   | >6.00E+0 | 5.00E+00 | 2.2E-04             | 2.0E-04 | 1.4E-04 | 6.5E-05 | 5.9E-05 |
| 6.00E+0                   | >8.00E+0 | 7.00E+00 | 2.4E-05             | 2.2E-05 | 1.5E-05 | 7.4E-06 | 6.7E-06 |
| 8.00E+0                   | >1.10E+1 | 9.50E+00 | 2.6E-06             | 2.4E-06 | 1.6E-06 | 8.4E-07 | 7.7E-07 |

D. J. Harrell  
MDS-07-99  
April 16, 1999  
Attachment V  
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**LOCKHEED MARTIN**

Lockheed Idaho Technologies Company

**INTERDEPARTMENTAL COMMUNICATION**

Date: November 26, 1997

To: N. E. Russell, MS 3765

From: D. R. Wenzel, MS 5209

*D. R. Wenzel*

Subject: CALCULATION OF RADIONUCLIDE INVENTORIES FOR SODIUM BEARING WASTES - Wen-23-97

- References:
- (1) Rebish, K. J., Nenni, J. A., letter to B. H. O'Brien, "Tank Farm Inventory - June, 1994," KJR-02-94/JAN-03-94, June 23, 1994.
  - (2) Radiation Shielding Information Center, *RSIC Computer Code Collection*, "ORIGEN2.1, Isotope Generation and Depletion Code Matrix Exponential Method," CCC-371, Oak Ridge, Tennessee, 1991.

The Waste Form and Characterization Scoping Study requires a knowledge of the radionuclide content of sodium bearing waste (SBW) at the ICPP in order to evaluate treatment options. Routine radiochemical analyses; however, do not identify all of the radionuclides present. Calculations have therefore been made to calculate complete radionuclide inventories for SBW.

SBW has been collected in the ICPP Tank Farm over the entire life of the ICPP. Six storage tanks, WM-180, -181, -183, -184, -185 and -186, currently contain SBW. Both the age of the wastes in the tanks and the analysis dates differ. The purpose of calculations was to calculate an average concentration of all radionuclides for the combined volume of all of the tanks.

Calculations have been based on the results of analytical analyses reported in Reference 1. All of the analytical analyses results were first decayed to a common decay time and then a weighted average of the activity in all six of the storage tanks was calculated. The ORIGEN2 code (Reference 2) was then used to calculate the activities for radionuclides that could not be established from analytical analyses.

Table 1 contains the calculated radionuclide inventories for SBW. While the activities for the actinides are relatively consistent, the concentration of fission products in Tank WM-183 is approximately 3 times higher than the calculated weighted average. It should be recognized that it probably will not be practical to blend the tanks to produce an average waste. Should wastes be processed directly from WM-183, direct radiation dose rates should be expected to be 3 times

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higher than what will be calculated for the average waste. While a rigorous uncertainty analysis was not done, the results for the weighted average activities for all of the waste storage tanks containing SBW are estimated to have an accuracy of  $\pm$  a factor of 2.

cc: C. M. Barnes, MS 3625  
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Table 1: Calculated Radionuclide Activities for Sodium Bearing Wastes in Ci/L as a Function of Decay Time

| Nuclide<br>(Actinides and Daughters) | Half-Life | 2016 | 2035    | Decay Time Since 2016 (yr) |         |         |         |
|--------------------------------------|-----------|------|---------|----------------------------|---------|---------|---------|
|                                      |           |      |         | 1E2                        | 5E2     | 1E3     |         |
| Tl207                                | 4.770E+00 | m    | 7.0E-11 | 9.4E-11                    | 1.5E-10 | 3.9E-10 | 6.6E-10 |
| Tl208                                | 3.053E+00 | m    | 8.5E-10 | 7.0E-10                    | 3.2E-10 | 6.9E-12 |         |
| Tl209                                | 2.200E+00 | m    | 1.0E-14 | 2.8E-14                    | 2.3E-13 | 4.3E-12 | 1.6E-11 |
| Pb209                                | 3.253E+00 | h    | 4.8E-13 | 1.3E-12                    | 1.1E-11 | 2.0E-10 | 7.5E-10 |
| Pb210                                | 2.226E+01 | yr   | 6.7E-12 | 1.3E-11                    | 6.0E-11 | 7.4E-10 | 2.3E-09 |
| Pb211                                | 3.610E+01 | m    | 7.0E-11 | 9.4E-11                    | 1.5E-10 | 3.9E-10 | 6.6E-10 |
| Pb212                                | 1.064E+01 | h    | 2.4E-09 | 2.0E-09                    | 9.0E-10 | 1.9E-11 | 1.6E-13 |
| Pb214                                | 2.680E+01 | m    | 1.6E-11 | 2.6E-11                    | 8.4E-11 | 7.4E-10 | 2.3E-09 |
| Bi210m                               | 3.000E+06 | yr   | 2.7E-25 | 2.7E-25                    | 2.7E-25 | 2.7E-25 | 2.7E-25 |
| Bi210                                | 5.013E+00 | d    | 6.7E-12 | 1.3E-11                    | 6.0E-11 | 7.4E-10 | 2.3E-09 |
| Bi211                                | 2.130E+00 | m    | 7.0E-11 | 9.4E-11                    | 1.5E-10 | 3.9E-10 | 6.6E-10 |
| Bi212                                | 6.055E+01 | m    | 2.4E-09 | 2.0E-09                    | 9.0E-10 | 1.9E-11 | 1.6E-13 |
| Bi213                                | 4.565E+01 | m    | 4.8E-13 | 1.3E-12                    | 1.1E-11 | 2.0E-10 | 7.5E-10 |
| Bi214                                | 1.990E+01 | m    | 1.6E-11 | 2.6E-11                    | 8.4E-11 | 7.4E-10 | 2.3E-09 |
| Po210                                | 1.384E+02 | d    | 6.7E-12 | 1.3E-11                    | 6.0E-11 | 7.4E-10 | 2.3E-09 |
| Po212                                | 3.000E-07 | s    | 1.5E-09 | 1.3E-09                    | 5.8E-10 | 1.2E-11 | 1.0E-13 |
| Po216                                | 1.460E-01 | s    | 2.4E-09 | 2.0E-09                    | 9.0E-10 |         |         |
| Po218                                | 3.050E+00 | m    | 1.6E-11 | 2.6E-11                    | 8.4E-11 | 7.4E-10 | 2.3E-09 |
| At217                                | 3.230E-02 | s    | 4.8E-13 | 1.3E-12                    | 1.1E-11 | 2.0E-10 | 7.5E-10 |
| Rn219                                | 3.960E+00 | s    | 7.0E-11 | 9.4E-11                    | 1.5E-10 | 3.9E-10 | 6.6E-10 |
| Rn220                                | 5.561E+01 | s    | 2.4E-09 | 2.0E-09                    | 9.0E-10 | 1.9E-11 |         |
| Rn222                                | 3.824E+00 | d    | 1.6E-11 | 2.6E-11                    | 8.4E-11 | 7.4E-10 | 2.3E-09 |
| Fr221                                | 4.800E+00 | m    | 4.8E-13 | 1.3E-12                    | 1.1E-11 | 2.0E-10 | 7.5E-10 |
| Fr223                                | 2.180E+01 | m    | 9.7E-13 | 1.3E-12                    | 2.1E-12 | 5.4E-12 | 9.1E-12 |
| Ra223                                | 1.143E+01 | d    | 7.0E-11 | 9.4E-11                    | 1.5E-10 | 3.9E-10 | 6.6E-10 |
| Ra224                                | 3.620E+00 | d    | 2.4E-09 | 2.0E-09                    | 9.0E-10 | 1.9E-11 | 1.6E-13 |
| Ra225                                | 1.480E+01 | d    | 4.8E-13 | 1.3E-12                    | 1.1E-11 | 2.0E-10 | 7.5E-10 |
| Ra226                                | 1.600E+03 | yr   | 1.6E-11 | 2.6E-11                    | 8.4E-11 | 7.4E-10 | 2.3E-09 |
| Ra228                                | 5.750E+00 | yr   | 8.3E-16 | 9.1E-16                    | 1.1E-15 | 1.9E-15 | 2.9E-15 |
| Ac225                                | 1.000E+01 | d    | 4.8E-13 | 1.3E-12                    | 1.1E-11 | 2.0E-10 | 7.5E-10 |
| Ac227                                | 2.177E+01 | yr   | 7.0E-11 | 9.4E-11                    | 1.5E-10 | 3.9E-10 | 6.6E-10 |
| Ac228                                | 6.130E+00 | h    | 8.3E-16 | 9.1E-16                    | 1.1E-15 | 1.9E-15 | 2.9E-15 |
| Th227                                | 1.872E+01 | d    | 6.9E-11 | 9.3E-11                    | 1.5E-10 | 3.8E-10 | 6.5E-10 |
| Th228                                | 1.913E+00 | yr   | 2.4E-09 | 2.0E-09                    | 9.0E-10 | 1.9E-11 | 1.6E-13 |
| Th229                                | 7.340E+03 | yr   | 4.8E-13 | 1.3E-12                    | 1.1E-11 | 2.0E-10 | 7.5E-10 |
| Th230                                | 7.700E+04 | yr   | 1.1E-09 | 1.3E-09                    | 2.1E-09 | 6.2E-09 | 1.1E-08 |
| Th231                                | 2.552E+01 | h    | 2.6E-08 | 2.6E-08                    | 2.6E-08 | 2.6E-08 | 2.6E-08 |
| Th232                                | 1.405E+10 | yr   | 9.0E-16 | 9.4E-16                    | 1.1E-15 | 1.9E-15 | 2.9E-15 |
| Th234                                | 2.410E+01 | d    | 2.6E-08 | 2.6E-08                    | 2.6E-08 | 2.6E-08 | 2.6E-08 |
| Pa231                                | 3.726E+04 | yr   | 1.2E-10 | 1.3E-10                    | 1.7E-10 | 3.9E-10 | 6.6E-10 |
| Pa233                                | 2.700E+01 | d    | 3.6E-06 | 3.6E-06                    | 3.6E-06 | 3.6E-06 | 3.6E-06 |
| Pa234m                               | 1.170E+00 | m    | 2.6E-08 | 2.6E-08                    | 2.6E-08 | 2.6E-08 | 2.6E-08 |
| Pa234                                | 6.700E+00 | h    | 3.3E-11 | 3.3E-11                    | 3.3E-11 | 3.3E-11 | 3.3E-11 |
| U232                                 | 7.200E+01 | yr   | 2.3E-09 | 1.9E-09                    | 8.8E-10 | 1.9E-11 | 1.5E-13 |
| U233                                 | 1.592E+05 | yr   | 3.0E-10 | 6.0E-10                    | 1.9E-09 | 8.2E-09 | 1.6E-08 |
| U234                                 | 2.445E+05 | yr   | 1.0E-06 | 1.0E-06                    | 1.1E-06 | 1.2E-06 | 1.2E-06 |
| U235                                 | 7.038E+08 | yr   | 2.6E-08 | 2.6E-08                    | 2.6E-08 | 2.6E-08 | 2.6E-08 |

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Table 1: Calculated Radionuclide Activities for Sodium Bearing Wastes in Ci/L as a Function of Decay Time (Continued)

| Nuclide                             | <u>Half-Life</u> | 2016 | 2035    | Decay Time Since 2016 (yr) |         |         |
|-------------------------------------|------------------|------|---------|----------------------------|---------|---------|
|                                     |                  |      |         | 1E2                        | 5E2     | 1E3     |
| (Actinides and Daughters Continued) |                  |      |         |                            |         |         |
| U236                                | 2.342E+07        | yr   | 4.1E-08 | 4.1E-08                    | 4.1E-08 | 4.2E-08 |
| U237                                | 6.750E+00        | d    | 4.3E-09 | 1.7E-09                    | 3.5E-11 | 8.7E-15 |
| U238                                | 4.470E+09        | yr   | 2.6E-08 | 2.6E-08                    | 2.6E-08 | 2.6E-08 |
| U240                                | 1.410E+01        | h    | 8.4E-16 | 8.4E-16                    | 8.4E-16 | 8.4E-16 |
| Np237                               | 2.140E+06        | yr   | 3.6E-06 | 3.6E-06                    | 3.6E-06 | 3.6E-06 |
| Np238                               | 2.117E+00        | d    | 8.9E-11 | 8.1E-11                    | 5.6E-11 | 9.1E-12 |
| Np239                               | 2.355E+00        | d    | 2.6E-08 | 2.6E-08                    | 2.6E-08 | 2.4E-08 |
| Pu236                               | 2.851E+00        | yr   | 1.4E-10 | 1.4E-12                    |         |         |
| Pu238                               | 8.775E+01        | yr   | 4.2E-04 | 3.6E-04                    | 1.9E-04 | 8.1E-06 |
| Pu239                               | 2.413E+04        | yr   | 6.7E-05 | 6.7E-05                    | 6.7E-05 | 6.5E-05 |
| Pu240                               | 6.569E+03        | yr   | 1.3E-05 | 1.2E-05                    | 1.2E-05 | 1.1E-05 |
| Pu241                               | 1.440E+01        | yr   | 1.7E-04 | 7.0E-05                    | 1.4E-06 | 3.5E-10 |
| Pu242                               | 3.758E+05        | yr   | 9.8E-09 | 9.8E-09                    | 9.8E-09 | 9.8E-09 |
| Pu244                               | 8.260E+07        | yr   | 8.4E-16 | 8.4E-16                    | 8.4E-16 | 8.4E-16 |
| Am241                               | 4.322E+02        | yr   | 6.6E-05 | 6.7E-05                    | 6.1E-05 | 3.2E-05 |
| Am242m                              | 1.520E+02        | yr   | 1.8E-08 | 1.6E-08                    | 1.1E-08 | 1.8E-09 |
| Am242                               | 1.602E+01        | h    | 1.8E-08 | 1.6E-08                    | 1.1E-08 | 1.8E-09 |
| Am243                               | 7.380E+03        | yr   | 2.6E-08 | 2.6E-08                    | 2.6E-08 | 2.5E-08 |
| Cm242                               | 1.628E+02        | d    | 1.5E-08 | 1.3E-08                    | 9.2E-09 | 1.5E-09 |
| Cm243                               | 2.850E+01        | yr   | 2.6E-08 | 1.6E-08                    | 2.3E-09 | 1.3E-13 |
| Cm244                               | 1.811E+01        | yr   | 1.3E-06 | 6.4E-07                    | 2.9E-08 | 6.5E-15 |
| Cm245                               | 8.500E+03        | yr   | 3.7E-10 | 3.7E-10                    | 3.7E-10 | 3.5E-10 |
| Cm246                               | 4.750E+03        | yr   | 2.4E-11 | 2.4E-11                    | 2.4E-11 | 2.3E-11 |
| Cm247                               | 1.560E+07        | yr   | 2.7E-17 | 2.7E-17                    | 2.7E-17 | 2.7E-17 |
| Cm248                               | 3.390E+05        | yr   | 2.9E-17 | 2.9E-17                    | 2.9E-17 | 2.9E-17 |
| Cf249                               | 3.506E+02        | yr   | 2.1E-17 | 2.0E-17                    | 1.7E-17 | 7.8E-18 |
| Cf250                               | 1.308E+01        | yr   | 8.8E-18 | 3.2E-18                    |         |         |
| Cf251                               | 9.000E+02        | yr   | 3.3E-19 | 3.3E-19                    | 3.1E-19 | 1.5E-19 |
| (Fission Products)                  |                  |      |         |                            |         |         |
| H 3                                 | 1.228E+01        | yr   | 6.6E-06 | 2.3E-06                    | 2.4E-08 | 4.3E-18 |
| Be 10                               | 1.600E+06        | yr   | 3.7E-12 | 3.7E-12                    | 3.7E-12 | 3.7E-12 |
| C 14                                | 5.730E+03        | yr   | 1.5E-10 | 1.5E-10                    | 1.4E-10 | 1.3E-10 |
| Se 79                               | 6.500E+04        | yr   | 5.4E-07 | 5.4E-07                    | 5.4E-07 | 5.3E-07 |
| Rb 87                               | 4.730E+10        | yr   | 3.6E-11 | 3.6E-11                    | 3.6E-11 | 3.6E-11 |
| Sr 90                               | 2.912E+01        | yr   | 4.7E-02 | 3.0E-02                    | 4.3E-03 | 3.2E-07 |
| Y 90                                | 6.410E+01        | h    | 4.7E-02 | 3.0E-02                    | 4.3E-03 | 3.2E-07 |
| Zr 93                               | 1.530E+06        | yr   | 2.7E-06 | 2.7E-06                    | 2.7E-06 | 2.7E-06 |
| Nb 93m                              | 1.360E+01        | yr   | 2.3E-06 | 2.5E-06                    | 2.6E-06 | 2.6E-06 |
| Nb 94                               | 2.030E+04        | yr   | 1.4E-06 | 1.4E-06                    | 1.4E-06 | 1.4E-06 |
| Tc 98                               | 4.200E+06        | yr   | 3.2E-12 | 3.2E-12                    | 3.2E-12 | 3.2E-12 |
| Tc 99                               | 2.130E+05        | yr   | 1.2E-05 | 1.2E-05                    | 1.2E-05 | 1.2E-05 |
| Rh102                               | 2.900E+00        | yr   | 4.8E-11 | 5.1E-13                    |         |         |
| Ru106                               | 3.682E+02        | d    | 1.5E-10 |                            |         |         |
| Rh106                               | 2.992E+01        | s    | 1.5E-10 |                            |         |         |
| Pd107                               | 6.500E+06        | yr   | 2.0E-08 | 2.0E-08                    | 2.0E-08 | 2.0E-08 |
| Ag108m                              | 1.270E+02        | yr   | 4.9E-13 | 4.4E-13                    | 2.8E-13 | 3.2E-14 |

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Table 1: Calculated Radionuclide Activities for Sodium Bearing Wastes in Ci/L as a Function of Decay Time (Continued)

| Nuclide                             | Half-Life  | 2016 | 2035    | Decay Time Since 2016 (yr) |         |         |
|-------------------------------------|------------|------|---------|----------------------------|---------|---------|
|                                     |            |      |         | 1E2                        | 5E2     | 1E3     |
| <i>(Fission Products Continued)</i> |            |      |         |                            |         |         |
| Cd113m                              | 1.360E+01  | yr   | 2.2E-06 | 9.0E-07                    | 1.9E-08 | 1.1E-16 |
| In115                               | 5.100E+15  | yr   | 1.2E-16 | 1.2E-16                    | 1.2E-16 | 1.2E-16 |
| Sn121m                              | 5.000E+01  | yr   | 6.9E-08 | 5.3E-08                    | 1.7E-08 | 6.7E-11 |
| Tel23                               | 1.000E+13  | yr   | 4.7E-19 | 4.7E-19                    | 4.7E-19 | 4.7E-19 |
| Sb125                               | 2.770E+00  | yr   | 6.2E-07 | 5.3E-09                    | 8.5E-18 |         |
| Tel25m                              | 5.800E+01  | d    | 1.5E-07 | 1.3E-09                    |         |         |
| Sn126                               | 1.000E+05  | yr   | 5.1E-07 | 5.1E-07                    | 5.1E-07 | 5.0E-07 |
| Sb126                               | 1.240E+01  | d    | 7.1E-08 | 7.1E-08                    | 7.1E-08 | 7.1E-08 |
| Sb126m                              | 1.900E+01  | m    | 5.1E-07 | 5.1E-07                    | 5.1E-07 | 5.0E-07 |
| I129                                | 1.570E+07  | yr   | 1.0E-05 | 1.0E-05                    | 1.0E-05 | 1.0E-05 |
| Cs134                               | 2.062E+00  | yr   | 3.3E-07 | 5.5E-10                    |         |         |
| Cs135                               | 2.300E+06  | yr   | 1.1E-06 | 1.1E-06                    | 1.1E-06 | 1.1E-06 |
| Cs137                               | 3.000E+01  | yr   | 4.6E-02 | 3.0E-02                    | 4.6E-03 | 4.4E-07 |
| Ba137m                              | 2.552E+00  | m    | 4.4E-02 | 2.8E-02                    | 4.3E-03 | 4.2E-07 |
| La138                               | 1.350E+11  | yr   | 2.4E-16 | 2.4E-16                    | 2.4E-16 | 2.4E-16 |
| Ce142                               | 1.050E+11  | yr   | 3.7E-11 | 3.7E-11                    | 3.7E-11 | 3.7E-11 |
| Ce144                               | 2.843E+02  | d    | 7.3E-12 |                            |         |         |
| Pr144                               | 1.728E+01  | m    | 7.3E-12 |                            |         |         |
| Pr144m                              | 7.200E+00  | m    | 8.7E-14 |                            |         |         |
| Nd144                               | 2.100E+15  | yr   | 2.0E-15 | 2.0E-15                    | 2.0E-15 | 2.0E-15 |
| Pm146                               | 2.020E+03  | d    | 1.2E-08 | 1.1E-09                    | 4.2E-14 |         |
| Sm146                               | 1.030E+08  | yr   | 3.4E-13 | 3.4E-13                    | 3.4E-13 | 3.4E-13 |
| Pm147                               | 2.623E+00  | yr   | 6.8E-06 | 4.5E-08                    | 2.3E-17 |         |
| Sm147                               | 1.070E+11  | yr   | 9.1E-12 | 9.1E-12                    | 9.1E-12 | 9.1E-12 |
| Sm148                               | 8.000E+15  | yr   | 4.7E-17 | 4.7E-17                    | 4.7E-17 | 4.7E-17 |
| Sm149                               | 1.000E+15  | yr   | 4.2E-18 | 4.2E-18                    | 4.2E-18 | 4.2E-18 |
| Eu150                               | 3.600E+01  | yr   | 1.4E-11 | 9.6E-12                    | 2.0E-12 | 9.1E-16 |
| Sm151                               | 9.000E+01  | yr   | 3.8E-04 | 3.2E-04                    | 1.7E-04 | 8.0E-06 |
| Eu152                               | 1.360E+01  | yr   | 1.6E-06 | 6.1E-07                    | 9.9E-09 | 1.4E-17 |
| Gd152                               | 1.080E+14  | yr   | 1.8E-18 | 1.8E-18                    | 1.9E-18 | 1.9E-18 |
| Eu154                               | 8.600E+00  | yr   | 7.0E-05 | 1.5E-05                    | 2.2E-08 |         |
| Eu155                               | 4.960E+00  | yr   | 3.3E-05 | 2.3E-06                    | 2.8E-11 |         |
| Ho166m                              | 1.2000E+03 | yr   | 5.7E-11 | 5.6E-11                    | 5.3E-11 | 4.2E-11 |
| Tm171                               | 1.920E+00  | yr   | 5.7E-18 |                            |         |         |
| <i>(Activation Products)</i>        |            |      |         |                            |         |         |
| Co 60                               | 5.271E+00  | yr   | 8.1E-06 | 6.7E-07                    | 1.6E-11 |         |
| Ni 63                               | 1.001E+02  | yr   | 3.5E-05 | 3.1E-05                    | 1.7E-05 |         |
| Total                               |            |      | 1.8E-01 | 1.2E-01                    | 1.8E-02 | 1.7E-04 |
|                                     |            |      |         |                            |         | 1.3E-04 |

D. J. Harrell  
MDS-07-99  
April 16, 1999  
Attachment V

**LOCKHEED MARTIN**

Document 7  
**Lockheed Idaho Technologies Company**

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**INTERDEPARTMENTAL COMMUNICATION**

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Date: March 2, 1998

To: K. N. Brewer, MS 5218

From: D. R. Wenzel, MS 5209

*D. R. Wenzel*

Subject: CALCULATION OF THE MASS OF INDIVIDUAL ELEMENTS IN ICPP  
WASTES FROM FISSION - Wen-05-98

- References:
- (1) D. R. Wenzel, Wen-20-97, to N. E. Russell, "Calculation of Radionuclide Inventories for Aluminum and Zirconium Calcines," dated October 14, 1997.
  - (2) D. R. Wenzel, Wen-23-97, to N. E. Russell, "Calculation of Radionuclide Inventories for Sodium Bearing Wastes," dated November 26, 1997.
  - (3) Radiation Shielding Information Center, RSIC Computer Code Collection, "ORIGEN2.1 Isotope Generation and Depletion Code Matrix Exponential Method," CCC-371, Oak Ridge, Tennessee, 1991.

As you have requested, the mass of individual elements in ICPP wastes that were formed during the fissioning of the reactor fuels have been calculated. The calculations performed are an extension to previous calculations (References 1 and 2) which calculated the radioactivity concentrations for the wastes. The ORIGEN2 code (Reference 3) was used to calculate the mass of the individual elements. The calculated mass of the individual elements as a function of decay time is presented in Tables 1, 2 and 3 respectively for aluminum calcine, zirconium calcine and sodium bearing wastes. As expected, the mass of most elements does not change with increased decay time as the majority of the mass of the elements has already decayed to a stable state.

cc: C. M. Barnes, MS 3625  
M. K. Branter, MS 5209  
G. W. Clarke, MS 4138  
G. G. Hall, MS 5209  
R. S. Herbst, MS 5218  
J. D. Law, MS 5218  
A. L. Olson, MS 5218

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M. Voracheck, MS 5208  
D. J. Wood, MS 5218  
EDF-CPP-98005

K. W. Brewer  
 March 2, 1998  
 Wen-05-98  
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Table 1: Elements in Aluminum Calcine (g/g Calcine) as a Function of Decay Time

| Element | 2016    | 2035    | Decay Time Since 2035 (yr) |         |         |
|---------|---------|---------|----------------------------|---------|---------|
|         |         |         | 100                        | 500     | 1000    |
| Li      | 4.8E-11 | 4.8E-11 | 4.8E-11                    | 4.8E-11 | 4.8E-11 |
| Be      | 1.9E-11 | 1.9E-11 | 1.9E-11                    | 1.9E-11 | 1.9E-11 |
| C       | 3.3E-12 | 3.3E-12 | 3.2E-12                    | 3.1E-12 | 2.9E-12 |
| Zn      | 6.8E-15 | 6.8E-15 | 6.8E-15                    | 6.8E-15 | 6.8E-15 |
| Ga      | 7.5E-14 | 7.5E-14 | 7.5E-14                    | 7.5E-14 | 7.5E-14 |
| Ge      | 7.7E-08 | 7.7E-08 | 7.7E-08                    | 7.7E-08 | 7.7E-08 |
| As      | 2.1E-08 | 2.1E-08 | 2.1E-08                    | 2.1E-08 | 2.1E-08 |
| Se      | 8.0E-06 | 8.0E-06 | 8.0E-06                    | 8.0E-06 | 8.0E-06 |
| Br      | 3.1E-06 | 3.1E-06 | 3.1E-06                    | 3.1E-06 | 3.2E-06 |
| Rb      | 6.1E-05 | 6.1E-05 | 6.1E-05                    | 6.1E-05 | 6.1E-05 |
| Sr      | 1.6E-04 | 1.5E-04 | 1.4E-04                    | 1.4E-04 | 1.4E-04 |
| Y       | 5.9E-09 | 3.8E-09 | 3.5E-10                    | 2.6E-14 | 1.7E-19 |
| Zr      | 5.9E-04 | 6.0E-04 | 6.2E-04                    | 6.2E-04 | 6.2E-04 |
| Nb      | 2.9E-09 | 3.8E-09 | 8.8E-09                    | 2.9E-08 | 5.3E-08 |
| Mo      | 4.3E-04 | 4.3E-04 | 4.3E-04                    | 4.3E-04 | 4.3E-04 |
| Tc      | 1.1E-04 | 1.1E-04 | 1.1E-04                    | 1.1E-04 | 1.1E-04 |
| Ru      | 2.1E-04 | 2.1E-04 | 2.1E-04                    | 2.1E-04 | 2.1E-04 |
| Rh      | 5.7E-05 | 5.7E-05 | 5.7E-05                    | 5.7E-05 | 5.7E-05 |
| Pd      | 3.7E-05 | 3.7E-05 | 3.7E-05                    | 3.7E-05 | 3.7E-05 |
| Ag      | 8.8E-07 | 8.8E-07 | 8.8E-07                    | 8.8E-07 | 8.8E-07 |
| Cd      | 2.1E-06 | 2.1E-06 | 2.1E-06                    | 2.1E-06 | 2.1E-06 |
| In      | 2.8E-07 | 2.8E-07 | 2.8E-07                    | 2.8E-07 | 2.8E-07 |
| Sn      | 4.4E-06 | 4.4E-06 | 4.4E-06                    | 4.4E-06 | 4.4E-06 |
| Sb      | 9.4E-07 | 9.4E-07 | 9.4E-07                    | 9.4E-07 | 9.4E-07 |
| Te      | 4.6E-05 | 4.6E-05 | 4.6E-05                    | 4.6E-05 | 4.6E-05 |
| I       | 2.1E-05 | 2.1E-05 | 2.1E-05                    | 2.1E-05 | 2.1E-05 |
| Cs      | 2.4E-04 | 2.3E-04 | 2.0E-04                    | 2.0E-04 | 2.0E-04 |
| Ba      | 2.9E-04 | 3.0E-04 | 3.3E-04                    | 3.3E-04 | 3.3E-04 |
| La      | 1.6E-04 | 1.6E-04 | 1.6E-04                    | 1.6E-04 | 1.6E-04 |
| Ce      | 3.2E-04 | 3.2E-04 | 3.2E-04                    | 3.2E-04 | 3.2E-04 |
| Pr      | 1.5E-04 | 1.5E-04 | 1.5E-04                    | 1.5E-04 | 1.5E-04 |
| Nd      | 5.4E-04 | 5.4E-04 | 5.4E-04                    | 5.4E-04 | 5.4E-04 |
| Pm      | 1.4E-11 | 1.0E-13 | 4.4E-20                    | 0.0E+00 | 0.0E+00 |
| Sm      | 1.1E-04 | 1.1E-04 | 1.1E-04                    | 1.1E-04 | 1.1E-04 |
| Eu      | 7.8E-06 | 8.2E-06 | 9.4E-06                    | 1.0E-05 | 1.0E-05 |
| Gd      | 2.6E-06 | 2.6E-06 | 2.6E-06                    | 2.6E-06 | 2.6E-06 |
| Tb      | 4.0E-08 | 4.0E-08 | 4.0E-08                    | 4.0E-08 | 4.0E-08 |
| Dy      | 8.7E-09 | 8.7E-09 | 8.7E-09                    | 8.7E-09 | 8.7E-09 |
| Ho      | 2.2E-10 | 2.2E-10 | 2.2E-10                    | 2.2E-10 | 2.2E-10 |
| Er      | 1.3E-10 | 1.3E-10 | 1.3E-10                    | 1.3E-10 | 1.3E-10 |
| Tm      | 1.6E-14 | 1.6E-14 | 1.6E-14                    | 1.6E-14 | 1.6E-14 |
| Er      | 1.3E-10 | 1.3E-10 | 1.3E-10                    | 1.3E-10 | 1.3E-10 |
| Yb      | 5.5E-16 | 5.5E-16 | 5.5E-16                    | 5.5E-16 | 5.5E-16 |
| Tl      | 1.2E-19 | 1.4E-19 | 1.6E-19                    | 1.7E-19 | 1.7E-19 |
| Pb      | 3.1E-12 | 3.4E-12 | 5.6E-12                    | 2.3E-11 | 6.3E-11 |
| Bi      | 4.1E-16 | 6.2E-16 | 2.1E-15                    | 2.9E-14 | 1.7E-13 |
| Po      | 9.6E-16 | 1.7E-15 | 6.1E-15                    | 2.5E-14 | 4.6E-14 |
| At      | 1.4E-26 | 1.5E-26 | 2.7E-26                    | 2.1E-25 | 7.0E-25 |
| Fr      | 8.5E-21 | 9.8E-21 | 1.1E-20                    | 1.3E-20 | 1.8E-20 |

K. W. Brewer

March 2, 1998

Wen-05-98

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Table 1: Elements in Aluminum Calcine (g/g Calcine) as a Function of Decay Time  
(Continued)

| Element | 2016    | 2035    | Decay Time Since 2035 (yr) |         |         |
|---------|---------|---------|----------------------------|---------|---------|
|         |         |         | 100                        | 500     | 1000    |
| Ra      | 9.4E-12 | 1.3E-11 | 3.4E-11                    | 1.2E-10 | 2.1E-10 |
| Ac      | 3.3E-13 | 3.8E-13 | 4.4E-13                    | 4.5E-13 | 4.6E-13 |
| Th      | 2.5E-08 | 2.5E-08 | 2.6E-08                    | 2.9E-08 | 3.2E-08 |
| Pa      | 6.7E-10 | 6.7E-10 | 6.7E-10                    | 6.8E-10 | 7.0E-10 |
| U       | 7.1E-05 | 7.1E-05 | 7.1E-05                    | 7.1E-05 | 7.1E-05 |
| Np      | 7.1E-06 | 7.1E-06 | 7.1E-06                    | 7.2E-06 | 7.2E-06 |
| Pu      | 4.4E-06 | 4.4E-06 | 4.3E-06                    | 4.2E-06 | 4.1E-06 |
| Am      | 1.6E-07 | 1.6E-07 | 1.4E-07                    | 7.3E-08 | 3.3E-08 |
| Cm      | 4.2E-13 | 2.2E-13 | 3.8E-14                    | 2.9E-14 | 2.8E-14 |
| Cf      | 6.4E-24 | 6.2E-24 | 5.1E-24                    | 2.3E-24 | 8.7E-25 |
| Totals  | 3.7E-03 | 3.7E-03 | 3.7E-03                    | 3.7E-03 | 3.7E-03 |

Table 2: Elements in Zirconium Calcine (g/g Calcine) as a Function of Decay Time

| Element | 2016    | 2035    | Decay Time Since 2035 (yr) |         |         |
|---------|---------|---------|----------------------------|---------|---------|
|         |         |         | 100                        | 500     | 1000    |
| Li      | 8.9E-12 | 8.9E-12 | 8.9E-12                    | 8.9E-12 | 8.9E-12 |
| Be      | 3.3E-12 | 3.3E-12 | 3.3E-12                    | 3.3E-12 | 3.3E-12 |
| Ga      | 1.6E-14 | 1.6E-14 | 1.6E-14                    | 1.6E-14 | 1.6E-14 |
| Ge      | 1.3E-08 | 1.3E-08 | 1.3E-08                    | 1.3E-08 | 1.3E-08 |
| As      | 3.7E-09 | 3.7E-09 | 3.7E-09                    | 3.7E-09 | 3.7E-09 |
| Se      | 1.4E-06 | 1.4E-06 | 1.4E-06                    | 1.4E-06 | 1.4E-06 |
| Br      | 5.4E-07 | 5.4E-07 | 5.4E-07                    | 5.4E-07 | 5.5E-07 |
| Rb      | 1.0E-05 | 1.0E-05 | 1.0E-05                    | 1.0E-05 | 1.0E-05 |
| Sr      | 2.0E-05 | 1.6E-05 | 1.1E-05                    | 1.0E-05 | 1.0E-05 |
| Y       | 1.3E-05 | 1.3E-05 | 1.3E-05                    | 1.3E-05 | 1.3E-05 |
| Zr      | 1.0E-04 | 1.1E-04 | 1.1E-04                    | 1.1E-04 | 1.1E-04 |
| Nb      | 3.2E-10 | 4.8E-10 | 1.3E-09                    | 4.8E-09 | 9.1E-09 |
| Mo      | 7.5E-05 | 7.5E-05 | 7.5E-05                    | 7.5E-05 | 7.5E-05 |
| Tc      | 1.9E-05 | 1.9E-05 | 1.9E-05                    | 1.9E-05 | 1.8E-05 |
| Ru      | 3.6E-05 | 3.6E-05 | 3.6E-05                    | 3.6E-05 | 3.6E-05 |
| Rh      | 9.9E-06 | 9.9E-06 | 9.9E-06                    | 9.9E-06 | 9.9E-06 |
| Pd      | 6.3E-06 | 6.3E-06 | 6.3E-06                    | 6.3E-06 | 6.3E-06 |
| Ag      | 1.5E-07 | 1.5E-07 | 1.5E-07                    | 1.5E-07 | 1.5E-07 |
| Cd      | 3.6E-07 | 3.6E-07 | 3.6E-07                    | 3.6E-07 | 3.6E-07 |
| In      | 4.8E-08 | 4.8E-08 | 4.9E-08                    | 4.9E-08 | 4.9E-08 |
| Sn      | 7.5E-07 | 7.5E-07 | 7.5E-07                    | 7.5E-07 | 7.5E-07 |
| Sb      | 1.6E-07 | 1.6E-07 | 1.6E-07                    | 1.6E-07 | 1.6E-07 |
| Te      | 8.0E-06 | 8.0E-06 | 8.0E-06                    | 8.0E-06 | 8.0E-06 |
| I       | 3.5E-06 | 3.5E-06 | 3.5E-06                    | 3.5E-06 | 3.5E-06 |
| Cs      | 5.5E-05 | 5.1E-05 | 4.5E-05                    | 4.4E-05 | 4.4E-05 |
| Ba      | 4.5E-05 | 4.9E-05 | 5.6E-05                    | 5.6E-05 | 5.6E-05 |
| La      | 2.8E-05 | 2.8E-05 | 2.8E-05                    | 2.8E-05 | 2.8E-05 |
| Ce      | 5.5E-05 | 5.5E-05 | 5.5E-05                    | 5.5E-05 | 5.5E-05 |
| Pr      | 2.6E-05 | 2.6E-05 | 2.6E-05                    | 2.6E-05 | 2.6E-05 |
| Nd      | 9.4E-05 | 9.4E-05 | 9.4E-05                    | 9.4E-05 | 9.4E-05 |

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Table 2: Elements in Zirconium Calcine (g/g Calcine) as a Function of Decay Time  
 (Continued)

| Element       | 2016           | 2035           | Decay Time Since 2035 (yr) |                |                |
|---------------|----------------|----------------|----------------------------|----------------|----------------|
|               |                |                | 100                        | 500            | 1000           |
| Pm            | 6.4E-10        | 4.2E-12        | 6.4E-20                    | 0.0E+00        | 0.0E+00        |
| Sm            | 1.9E-05        | 1.9E-05        | 1.9E-05                    | 1.8E-05        | 1.8E-05        |
| Eu            | 1.2E-06        | 1.3E-06        | 1.7E-06                    | 2.0E-06        | 2.0E-06        |
| Gd            | 4.4E-07        | 4.4E-07        | 4.4E-07                    | 4.4E-07        | 4.4E-07        |
| Tb            | 6.6E-09        | 6.6E-09        | 6.6E-09                    | 6.6E-09        | 6.6E-09        |
| Dy            | 1.3E-09        | 1.3E-09        | 1.3E-09                    | 1.3E-09        | 1.3E-09        |
| Ho            | 3.1E-11        | 3.1E-11        | 3.1E-11                    | 3.1E-11        | 3.1E-11        |
| Er            | 1.8E-11        | 1.8E-11        | 1.8E-11                    | 1.8E-11        | 1.8E-11        |
| Tm            | 6.0E-16        | 6.0E-16        | 6.0E-16                    | 6.0E-16        | 6.0E-16        |
| Er            | 1.8E-11        | 1.8E-11        | 1.8E-11                    | 1.8E-11        | 1.8E-11        |
| Yb            | 1.4E-17        | 1.4E-17        | 1.4E-17                    | 1.4E-17        | 1.4E-17        |
| Tl            | 5.2E-20        | 4.8E-20        | 2.9E-20                    | 1.9E-20        | 2.3E-20        |
| Pb            | 3.9E-13        | 6.5E-13        | 1.5E-12                    | 3.2E-12        | 7.7E-12        |
| Bi            | 6.1E-18        | 1.5E-17        | 3.4E-16                    | 1.7E-14        | 1.2E-13        |
| Po            | 9.2E-19        | 3.9E-18        | 7.7E-17                    | 1.8E-15        | 6.7E-15        |
| At            | 4.4E-28        | 1.1E-27        | 1.0E-26                    | 1.4E-25        | 5.2E-25        |
| Fr            | 6.4E-22        | 8.1E-22        | 1.1E-21                    | 2.6E-21        | 6.3E-21        |
| Ra            | 1.8E-14        | 5.1E-14        | 5.4E-13                    | 8.3E-12        | 3.0E-11        |
| Ac            | 2.5E-14        | 3.1E-14        | 4.0E-14                    | 5.0E-14        | 6.0E-14        |
| Th            | 1.9E-10        | 3.0E-10        | 9.5E-10                    | 4.0E-09        | 8.0E-09        |
| Pa            | 5.9E-11        | 6.0E-11        | 6.3E-11                    | 7.6E-11        | 9.2E-11        |
| U             | 5.1E-05        | 5.1E-05        | 5.2E-05                    | 5.2E-05        | 5.2E-05        |
| Np            | 5.2E-06        | 5.2E-06        | 5.3E-06                    | 5.5E-06        | 5.7E-06        |
| Pu            | 6.0E-06        | 5.8E-06        | 5.3E-06                    | 4.9E-06        | 4.8E-06        |
| Am            | 4.9E-07        | 5.2E-07        | 4.7E-07                    | 2.5E-07        | 1.1E-07        |
| Cm            | 2.6E-13        | 2.4E-13        | 1.5E-13                    | 2.5E-14        | 2.5E-15        |
| <b>Totals</b> | <b>6.9E-04</b> | <b>6.9E-04</b> | <b>6.9E-04</b>             | <b>6.9E-04</b> | <b>6.9E-04</b> |

Table 3: Elements in SBW (g/L) as a Function of Decay Time

| Element | 2016    | 2035    | Decay Time Since 2035 (yr) |         |         |
|---------|---------|---------|----------------------------|---------|---------|
|         |         |         | 100                        | 500     | 1000    |
| Li      | 3.5E-10 | 3.5E-10 | 3.5E-10                    | 3.5E-10 | 3.5E-10 |
| Be      | 1.9E-10 | 1.9E-10 | 1.9E-10                    | 1.9E-10 | 1.9E-10 |
| Ga      | 1.7E-12 | 1.7E-12 | 1.7E-12                    | 1.7E-12 | 1.7E-12 |
| Ge      | 8.2E-07 | 8.2E-07 | 8.2E-07                    | 8.2E-07 | 8.2E-07 |
| As      | 2.3E-07 | 2.3E-07 | 2.3E-07                    | 2.3E-07 | 2.3E-07 |
| Se      | 8.1E-05 | 8.1E-05 | 8.1E-05                    | 8.1E-05 | 8.1E-05 |
| Br      | 3.1E-05 | 3.1E-05 | 3.1E-05                    | 3.1E-05 | 3.1E-05 |
| Rb      | 6.1E-04 | 6.1E-04 | 6.1E-04                    | 6.1E-04 | 6.1E-04 |
| Sr      | 9.3E-04 | 8.1E-04 | 6.2E-04                    | 5.9E-04 | 5.9E-04 |
| Y       | 7.8E-04 | 7.8E-04 | 7.8E-04                    | 7.8E-04 | 7.8E-04 |
| Zr      | 4.8E-03 | 5.0E-03 | 5.2E-03                    | 5.2E-03 | 5.2E-03 |
| Mo      | 4.4E-03 | 4.4E-03 | 4.4E-03                    | 4.4E-03 | 4.4E-03 |
| Nb      | 7.5E-06 | 7.6E-06 | 7.6E-06                    | 7.7E-06 | 7.8E-06 |
| Tc      | 7.3E-04 | 7.3E-04 | 7.3E-04                    | 7.3E-04 | 7.3E-04 |
| Ru      | 2.2E-03 | 2.2E-03 | 2.2E-03                    | 2.2E-03 | 2.2E-03 |

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Table 3: Elements in SBW (g/L) as a Function of Decay Time (Continued)

| <u>Element</u> | <u>2016</u>    | <u>2035</u>    | <u>Decay Time Since 2035 (yr)</u> |                |                |
|----------------|----------------|----------------|-----------------------------------|----------------|----------------|
|                |                |                | <u>100</u>                        | <u>500</u>     | <u>1000</u>    |
| Rh             | 4.8E-04        | 4.8E-04        | 4.8E-04                           | 4.8E-04        | 4.8E-04        |
| Pd             | 4.8E-04        | 4.8E-04        | 4.8E-04                           | 4.8E-04        | 4.8E-04        |
| Ag             | 8.8E-06        | 8.8E-06        | 8.8E-06                           | 8.8E-06        | 8.8E-06        |
| Cd             | 2.6E-05        | 2.6E-05        | 2.6E-05                           | 2.6E-05        | 2.6E-05        |
| In             | 2.0E-06        | 2.1E-06        | 2.1E-06                           | 2.1E-06        | 2.1E-06        |
| Sn             | 5.0E-05        | 5.0E-05        | 5.0E-05                           | 5.0E-05        | 5.0E-05        |
| Sb             | 1.0E-05        | 1.0E-05        | 1.0E-05                           | 1.0E-05        | 1.0E-05        |
| Te             | 4.7E-04        | 4.7E-04        | 4.7E-04                           | 4.7E-04        | 4.7E-04        |
| I              | 5.8E-02        | 5.8E-02        | 5.8E-02                           | 5.8E-02        | 5.8E-02        |
| Cs             | 3.0E-03        | 2.8E-03        | 2.5E-03                           | 2.4E-03        | 2.4E-03        |
| Ba             | 2.9E-03        | 3.1E-03        | 3.4E-03                           | 3.4E-03        | 3.4E-03        |
| La             | 1.6E-03        | 1.6E-03        | 1.6E-03                           | 1.6E-03        | 1.6E-03        |
| Ce             | 3.2E-03        | 3.2E-03        | 3.2E-03                           | 3.2E-03        | 3.2E-03        |
| Pr             | 1.5E-03        | 1.5E-03        | 1.5E-03                           | 1.5E-03        | 1.5E-03        |
| Nd             | 5.5E-03        | 5.5E-03        | 5.5E-03                           | 5.5E-03        | 5.5E-03        |
| Pm             | 7.3E-09        | 5.1E-11        | 9.3E-17                           | 0.0E+00        | 0.0E+00        |
| Sm             | 1.1E-03        | 1.1E-03        | 1.0E-03                           | 1.0E-03        | 1.0E-03        |
| Eu             | 9.9E-05        | 1.0E-04        | 1.1E-04                           | 1.1E-04        | 1.1E-04        |
| Gd             | 5.2E-05        | 5.2E-05        | 5.2E-05                           | 5.2E-05        | 5.2E-05        |
| Tb             | 4.3E-07        | 4.3E-07        | 4.3E-07                           | 4.3E-07        | 4.3E-07        |
| Dy             | 1.3E-07        | 1.3E-07        | 1.3E-07                           | 1.3E-07        | 1.3E-07        |
| Ho             | 5.6E-09        | 5.6E-09        | 5.6E-09                           | 5.5E-09        | 5.5E-09        |
| Er             | 2.2E-09        | 2.2E-09        | 2.2E-09                           | 2.2E-09        | 2.2E-09        |
| Tm             | 1.1E-12        | 1.1E-12        | 1.1E-12                           | 1.1E-12        | 1.1E-12        |
| Er             | 2.2E-09        | 2.2E-09        | 2.2E-09                           | 2.2E-09        | 2.2E-09        |
| Yb             | 1.9E-13        | 1.9E-13        | 1.9E-13                           | 1.9E-13        | 1.9E-13        |
| Tl             | 1.3E-17        | 1.1E-17        | 5.7E-18                           | 2.1E-18        | 3.4E-18        |
| Pb             | 1.9E-10        | 2.6E-10        | 4.7E-10                           | 7.4E-10        | 1.1E-09        |
| Bi             | 3.8E-15        | 5.7E-15        | 1.8E-14                           | 2.8E-13        | 1.6E-12        |
| Po             | 1.5E-15        | 3.0E-15        | 1.3E-14                           | 1.6E-13        | 5.2E-13        |
| At             | 1.5E-25        | 1.7E-25        | 3.0E-25                           | 1.9E-24        | 6.4E-24        |
| Fr             | 2.4E-20        | 3.2E-20        | 5.3E-20                           | 1.5E-19        | 2.9E-19        |
| Ra             | 1.6E-11        | 2.6E-11        | 8.5E-11                           | 7.5E-10        | 2.4E-09        |
| Ac             | 8.9E-13        | 1.2E-12        | 2.0E-12                           | 5.2E-12        | 8.9E-12        |
| Th             | 6.4E-08        | 7.4E-08        | 1.1E-07                           | 3.3E-07        | 5.9E-07        |
| Pa             | 2.2E-09        | 2.4E-09        | 3.4E-09                           | 8.0E-09        | 1.4E-08        |
| U              | 8.9E-02        | 8.9E-02        | 8.9E-02                           | 8.9E-02        | 8.9E-02        |
| No             | 5.3E-05        | 5.4E-05        | 5.6E-05                           | 6.4E-05        | 6.9E-05        |
| Pu             | 1.2E-03        | 1.2E-03        | 1.1E-03                           | 1.1E-03        | 1.1E-03        |
| Am             | 1.9E-05        | 2.0E-05        | 1.8E-05                           | 9.5E-06        | 4.3E-06        |
| Cm             | 1.9E-08        | 1.0E-08        | 2.6E-09                           | 2.1E-09        | 2.0E-09        |
| Cf             | 5.4E-18        | 5.1E-18        | 4.4E-18                           | 2.0E-18        | 8.0E-19        |
| <b>Totals</b>  | <b>1.8E-01</b> | <b>1.8E-01</b> | <b>1.8E-01</b>                    | <b>1.8E-01</b> | <b>1.8E-01</b> |

D. J. Harrell  
MDS-07-99  
April 16, 1999  
Attachment V  
Document 8

**LOCKHEED MARTIN**

Lockheed Idaho Technologies Company

**INTERDEPARTMENTAL COMMUNICATION**

Date: March 5, 1999

To: M. D. Staiger, MS 3211

From: D. R. Wenzel, MS 5209

Subject: REVISION OF I-129 ACTIVITY IN SODIUM BEARING WASTE  
CALCULATIONS – Wen-15-99

- References:
- (1) Wenzel, D. R., Wen-23-97, to N. E. Russell, "Calculation of Radionuclide Inventories for Sodium Bearing," dated November 26, 1997.
  - (2) Wenzel, D. R., *Evaluation of Radionuclide Inventory for Sodium Bearing Waste*, EDF CPP-97080 and EDF-FDO-006, Functional File Numbers 1000-70 and C-04, December, 1997.
  - (3) Radiation Shielding Information Center, *RSIC Computer Code Collection*, ORIGEN2.1, Isotope Generation and Depletion Code Matrix Exponential Method, CCC-371, Oak Ridge, Tennessee, 1991.
  - (4) Rebish, K. J., Nenni, J. A., letter to B. H. O'Brien, "Tank Farm Inventory – June, 1994," KJR-02-94/JAN-03-94, June 23, 1994.
  - (5) Caldwell, M. A. letter to S. S. Bodner, "Analysis of Na-Waste Tanks," Cald-8-83, October 13, 1983.

Radionuclide inventories were calculated in 1997 for sodium bearing wastes (SBW) (References 1 and 2). A decision made at that time was to calculate the radionuclide inventories as well as possible using the ORIGEN2 code (Reference 3) and to replace calculated inventories with actual measured results when measured results were available. Because the I-129 concentrations established from the analytical results obtained from Reference 4 for SBW are higher than anticipated, a review of analytical data has been made. The analytical results for I-129 summarized in Reference 4 were found not to be consistent with previous analytical measurements summarized in Reference 5. The conclusion is that the I-129 concentration in SBW should be reduced from the previously recommended concentration of 1.0E-5 Ci/L to 6.6E-8 Ci/L. The basis for this conclusion follows.

The amount of I-129 reported in Reference 1 to be in SBW was based on analytical results reported in Reference 4. Table 1 presents a summary of these results. As can be seen, all of the results for I-129 are reported as less than values except that for WM-184. This places that data as suspect; however, the weighted average for I-129 was close to the measured results for WM-184,

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Table 1: I-129 Analytical Results from Reference 4 (Decayed to 1997)

| Tank         | mCi/L     |          | I-129 / Cs-137 |
|--------------|-----------|----------|----------------|
|              | I-129     | Cs-137   |                |
| WM-180       | <1.41E-05 | 3.02E+01 | <4.67E-07      |
| WM-181       | <7.57E-06 | 2.98E+01 | <2.54E-07      |
| WM-183       | <1.18E-02 | 2.34E+02 | <5.04E-05      |
| WM-184       | 1.00E-02  | 2.37E+01 | 4.22E-04       |
| WM-185       | <3.90E-02 | 1.14E+02 | <3.42E-04      |
| Weighted Avg | <1.03E-02 | 7.02E+01 | <1.47E-04      |

the only tank without a less than value for I-129. An I-129 value of 1.0E-5 Ci/L was therefore reported in References 1 and 2 based on the analytical results. It has now been learned that the measurement of 1.00E-2 mCi/L for WM-184 was considered suspect several years ago by Bob Schindler. Discussions between Schindler and Ben Hunter concluded at that time that the I-129 results for WM-184 should have also been reported as less than value. With this knowledge, it can be concluded the analytical results for I-129 reported in Reference 4 cannot be used to establish the amount of I-129 in the SBW.

Subsequent investigation has shown that SBW was also sampled and analyzed in 1983 (Reference 5). The results of I-129 and Cs-137 measurements obtained from the 1983 samples are presented in Table 2.

Table 2: I-129 Analytical Results from Reference 5

| Tank   | mCi/L    |          |
|--------|----------|----------|
|        | I-129    | Cs-137   |
| WM-180 | 2.06E-05 | 1.02E+02 |
| WM-181 | 1.12E-05 | 2.89E+01 |
| WM-184 | 6.65E-05 | 1.89E+01 |
| WM-186 | 2.82E-05 | 3.54E+01 |

The data for a given tank cannot be compared directly between the different analysis periods because of waste concentrating activities done subsequent to the analyses done in the 1988 to 1993 time period. Also, additional SBW was added to the waste tanks subsequent to the 1983 sampling time. However, the weighted average of the ratio of I-129 to Cs-137 can be used to determine the amount of I-129 in the current SBW provided the Cs-137 is decay corrected. The activities decayed to the 1997 data are presented in Table 3.

D. Staiger  
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Table 3: I-129 Adjusted Analytical Results from Reference 5

| Tank         | mCi/L    |          | I-129 / Cs-137 |
|--------------|----------|----------|----------------|
|              | I-129    | Cs-137   |                |
| WM-180       | 2.06E-05 | 7.33E+01 | 2.81E-07       |
| WM-181       | 1.12E-05 | 2.08E+01 | 5.38E-07       |
| WM-184       | 6.65E-05 | 1.36E+01 | 4.89E-06       |
| WM-186       | 2.82E-05 | 2.55E+01 | 1.06E-06       |
| Weighted Avg | 3.15E-05 | 3.33E+01 | 9.46E-07       |

Knowing the weighted ratio of I-129/Cs-137, the concentration of I-129 in SBW can be estimated by multiplying this ratio by the concentration of Cs-137 established in Reference 2. Multiplying 7.02E+2 mCi/L of Cs-137 by the ratio of 9.46E-07, a concentration of 6.6E-5 mCi/L or 6.6E-8 Ci/L has been established for I-129.

The established concentration of 6.6E-8 Ci/L was compared to the theoretical calculations made in Reference 2 using the ORIGEN2. The established concentration of 6.6 E-8 Ci/L is a factor of 2.2 higher than that calculated using ORIGEN2. Because I-129 did not behave the same as the other fission products in the plant, the use of the theoretical calculated concentration is not recommended. However, agreement within a factor of 2.2 is encouraging and adds confidence to the reestablished I-129 concentration in SBW.

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